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Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-65

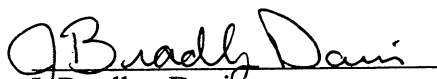
*Gregory N. Katnik, Barry C. Bowen, J. Bradley Davis,
Vehicle Engineering/Mechanical System Division/ET Section,
Kennedy Space Center, Florida*

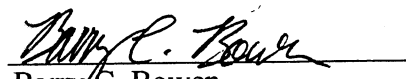



**DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-65**


July 8, 1994

Prepared By:

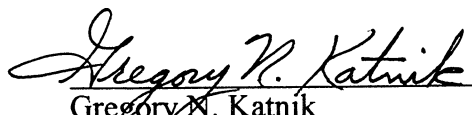

J. Bradley Davis
Digital Imaging Systems
NASA/Kennedy Space Center


Barry C. Bowen
Infrared Scanning Systems
NASA/Kennedy Space Center


Jorge E. Rivera
Mechanical/Structural Systems
NASA/Kennedy Space Center


Robert F. Speece
Thermal Protection Systems
NASA/Kennedy Space Center

Approved:


Gregory N. Katnik
Shuttle Ice/Debris Systems
NASA/Kennedy Space Center
TV-MSD-22

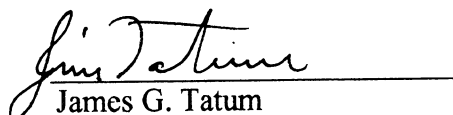

James G. Tatum
Chief, ET Mechanical Systems
NASA/Kennedy Space Center
TV-MSD-22

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center (KSC) Photo/Video Analysis, reports from Johnson Space Center, Marshall Space Flight Center, and Rockwell International - Downey are also included in this document to provide an integrated assessment of the mission.

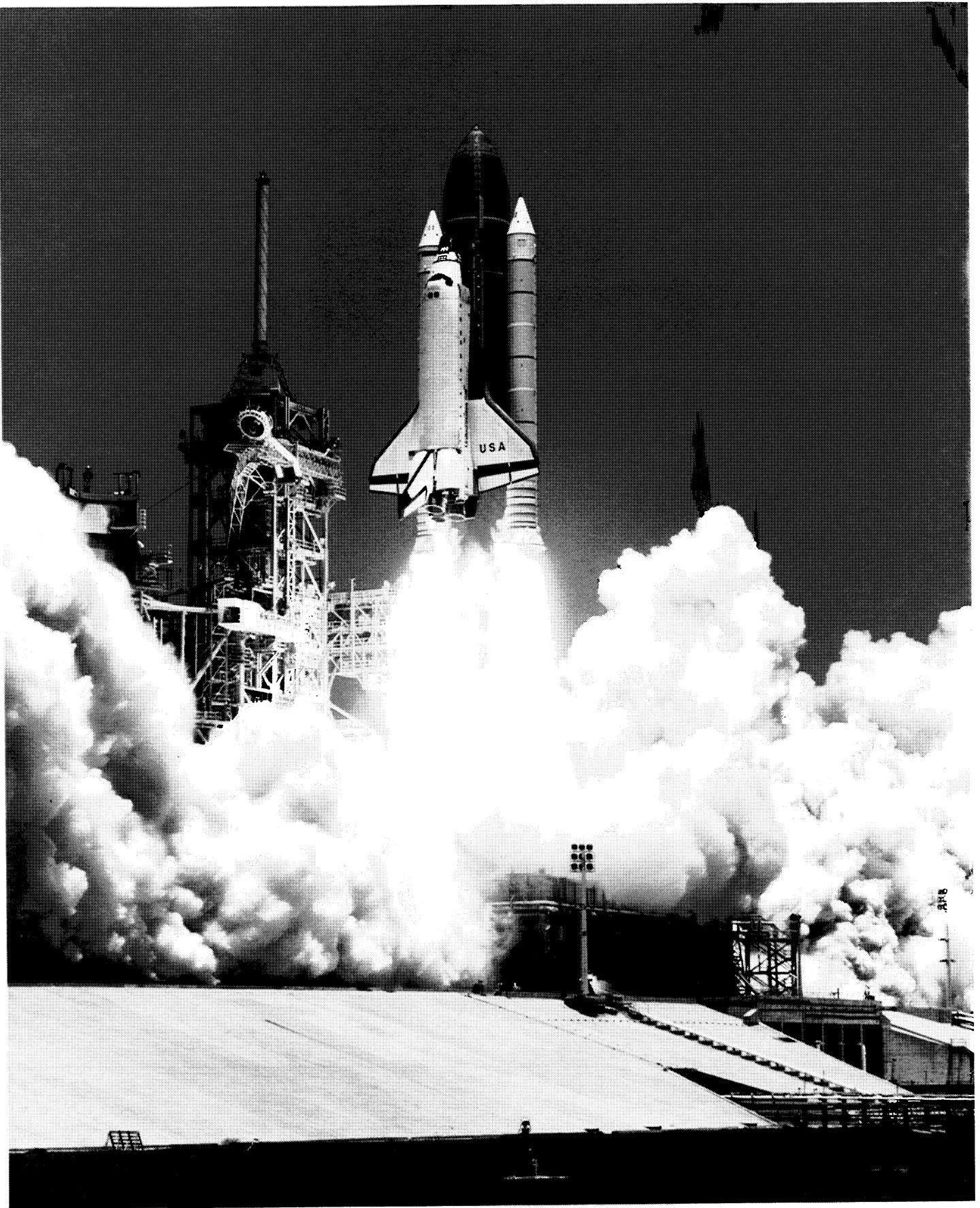


Photo 1 : Launch of Shuttle Mission STS-65



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1.0 Summary

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 7 July 1994. The detailed walkdown of Launch Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (17th flight), ET-64 (LWT 57), and BI-066 SRB's. There were no significant debris issues or vehicle anomalies.

The vehicle was cryoloaded on 8 July 1994. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. There were no icing conditions outside of the established data base and no IPR's were taken. During the Ice Inspection at T-3 hours and holding, two pieces of debris (a pen cap and a washer/retainer from the Orbiter 50-1 door closeout) were removed from the top of the LH2 TSM using a 30 foot pole.

After the 12:43 p.m. EDT launch on 8 July 1994, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers had closed properly. Erosion of the blast covers was typical and there were no burn-throughs of the material. A sheet metal roof was ripped off the new ECLSS building near the FSS by the SRB plume as the vehicle cleared the tower. Scattering of the sheet metal west of the pad did not pose a threat to the vehicle.

A total of 132 films and videos were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. Localized flow condensation occurred on numerous parts of the vehicle for a longer than usual period of time during ascent. A white vapor cloud formed at T+57.485 seconds MET as the vehicle passed through a layer of atmospheric moisture. The vehicle was traveling Mach 1.3 at an altitude of 34,000 feet (approximately). The vapor cloud was an aerodynamic induced phenomenon associated with the atmospheric conditions at that time. Similar occurrences of vehicle induced atmospheric condensation have been observed on past flights (STS-48 and -54) and is not considered a vehicle anomaly.

On-orbit photography revealed no major vehicle damage or lost flight hardware that would have been a safety of flight concern. A piece of foam, approximately 12 inches by 8 inches by 1 inch, appeared to originate from the aft surface of the LH2 ET/ORB umbilical cable tray. Loss of TPS this thick may have exposed substrate. Two divots, 6 to 8 inches in diameter, were present in the LH2 tank-to-intertank flange closeout immediately to the +Y side of the PAL ramp. Both divots went to substrate and exposed the primer. Both bipod jack pad closeouts were intact. Although not definitive in the film, the lightning contact strip across the forward part of the LO2 ET/ORB umbilical and as many as three of the four smaller lightning contact strips may have been missing. A light colored debris object floating near the crossbeam may be the large contact strip from the top of the umbilical.

One anomaly was detected in the landing film review. Pilot chute deployment from the aft end of the Orbiter appeared nominal. The chute risers were subsequently contacted by the drag chute door caught in aerodynamic vortices aft of the Orbiter. Function of the pilot chute was not affected and movement of the drag chute door did not threaten drag chute deployment, which appeared nominal.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums had a combined total of 35 MSA-2 debonds over fasteners. Hypalon paint was blistered/ missing where BTA closeouts had been applied. All of the holddown post DCS plungers were seated and appeared to have functioned properly.

A post landing inspection of OV-102 after landing at KSC revealed the Orbiter TPS sustained a total of 151 hits, of which 21 had a major dimension of 1-inch or greater. The Orbiter lower surface had a total of 123 hits, of which 17 had a major dimension of 1-inch or greater. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of debris hits was slightly greater than average and the number of hits 1-inch or larger was average. The ET/Orbiter separation devices functioned properly. No debris was found on the runway below the umbilical cavities.

The largest tile damage site measured 6.5" x 2.9" x 1.9" (50 percent of the area to substrate) on the LH OMS pod leading edge tile V070-396450-007 and was most likely the result of an ice impact during reentry. Ice may have formed on the waste water dump nozzle due to an on-orbit problem with this system. On-orbit photos taken seven days into the mission confirmed the damage was not present at that time.

LH wing leading edge RCC panel #5 sustained a micrometeorite hit in the upper center area. The impact site measured 0.078 inches in diameter with a depth of 0.025 inches. Post landing inspections in the OPF showed no penetration.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples that emanated from window protective covers, SRB BSM exhaust, Orbiter TPS, RCS thruster paper covers and adhesive, and paints/primers from various sources. SRB hypalon paint particulate was present in the lower surface tile samples. However, the paint particulate was not fused to the fibrous tile material and is not considered a debris hit material residual. These residual sampling data do not indicate a single source of damaging debris as all of the other materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of 8 Post Launch Anomalies were observed during the STS-65 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS/Photographic Analysis Team briefing for launch activities was conducted on 7 July 1994 at 1230 hours. These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC	Chief, ET Mechanical Systems
G. Katnik	NASA - KSC	Shuttle Ice/Debris Systems
B. Davis	NASA - KSC	Debris, IR, Photo Analysis
R. Speece	NASA - KSC	Lead, Thermal Protection Sys
B. Bowen	NASA - KSC	ET Processing/Ice/Debris/TPS
J. Rivera	NASA - KSC	Lead, ET Mechanisms/Structures
M. Bassignani	NASA - KSC	ET Processing
J. Cawby	LSOC - SPC	ET Mechanical Systems
J. Blue	LSOC - SPC	ET Processing
J. Kerckmar	LSOC - SPC	ET Processing
G. Fales	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
M. Wollam	LSOC - SPC	ET Processing
W. Richards	LSOC - SPC	ET Processing
Z. Byrns	NASA - KSC	Level II Integration
J. Stone	RI - DNY	Aero, Debris Assess, LVL II Integ
K. Mayer	RI - LSS	Rockwell Integration
R. Hillard	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing
K. Ely	MMMSS- LSS	ET Processing
M. Barber	LSOC - SPC	Safety

3.0 LAUNCH

STS-65 was launched at 16:43:00.069 GMT (12:43 p.m. local) on 8 July 1994.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 7 July 1994 from 1330 to 1430 hours. The detailed walkdown of Pad 39A and MLP-3 also included the primary flight elements OV-102 Columbia (17th flight), ET-64 (LWT 57), and BI-066 SRB's. There were no significant debris issues or vehicle anomalies.

3.2 ICE/FROST INSPECTION

The Ice Inspection of the cryoloaded vehicle was performed on 8 July 1994 from 0800 to 1000 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no conditions outside of the established data base and no IPR's were taken. Ambient weather conditions at the time of the inspection were:

Temperature:	73.0 Degrees F
Relative Humidity:	75.5 Percent
Wind Speed:	13.5 Knots
Wind Direction:	086 Degrees

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to scan the vehicle for unusual temperature gradients, particularly those areas not visible from remote fixed scanners, and to obtain a random sampling of vehicle surface temperature measurements to thermally characterize the vehicle.

3.3 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers were intact and dry. Less than usual ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the portable STI radiometer ranged from 80 to 84 degrees F. In comparison, temperatures measured by a handheld Minolta Cyclops spot radiometer were 80 to 84 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures between 78-86 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 81 degrees F, which was within the required range of 44-86 degrees F.

3.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Ice Team observed no ice/frost accumulations on the LO2 tank though light condensate was present on the LO2 tank barrel section. There were no TPS anomalies. The portable STI measured surface temperatures that averaged 79 degrees F on the ogive and 75 degrees F on the barrel section. In comparison, the Cyclops spot radiometer measured temperatures that averaged 79 degrees F on the ogive and 75 degrees F on the barrel section. SURFICE predicted temperatures of 74 degrees F on the ogive and 70 degrees F on the barrel.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate. The portable STI measured an average surface temperature of 80 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Very light condensate, but no ice or frost, was present on the acreage. The portable STI measured surface temperatures that averaged 72 degrees F on the upper LH2 tank and 75 degrees F on the lower LH2 tank. In comparison, the Cyclops spot radiometer measured a temperature of 75 degrees F on the upper LH2 tank and 76 degrees F on the lower LH2 tank. SURFICE predicted temperatures of 66 degrees F on the upper LH2 tank and 75 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts.

A smaller than usual crack, 2 inches long by 1/4 inch wide, was present in the -Y ET/SRB cable tray forward surface TPS. The presence of the crack was acceptable for flight per the NSTS-08303 criteria.

Less than usual amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. The 17-inch flapper valve actuator access port foam plug was properly closed out. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, consisted of four OTV recorded items:

Anomaly 001 documented ice/frost formations in the LO2 feedline support brackets and bellows.

Anomaly 002 documented a 2 inch by 1/4 inch crack in the forward surface TPS of the -Y vertical strut.

Anomaly 003 documented ice/frost formation on the -Y longeron/thrust strut interface adjacent to the witness panel closeout.

Anomaly 004 documented ice/frost formations on the LO2 ET/ORB umbilical purge vents and the LH2 ET/ORB umbilical purge vents, recirculation line bellows, and purge barrier.

3.6 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the GUCP.

Two pieces of debris, a pen cap and a washer/retainer from the Orbiter 50-1 door, were removed from the top of the LH2 TSM using a 30 foot pole.

No ET nosecone/footprint damage was visible after the GOX vent hood was retracted.

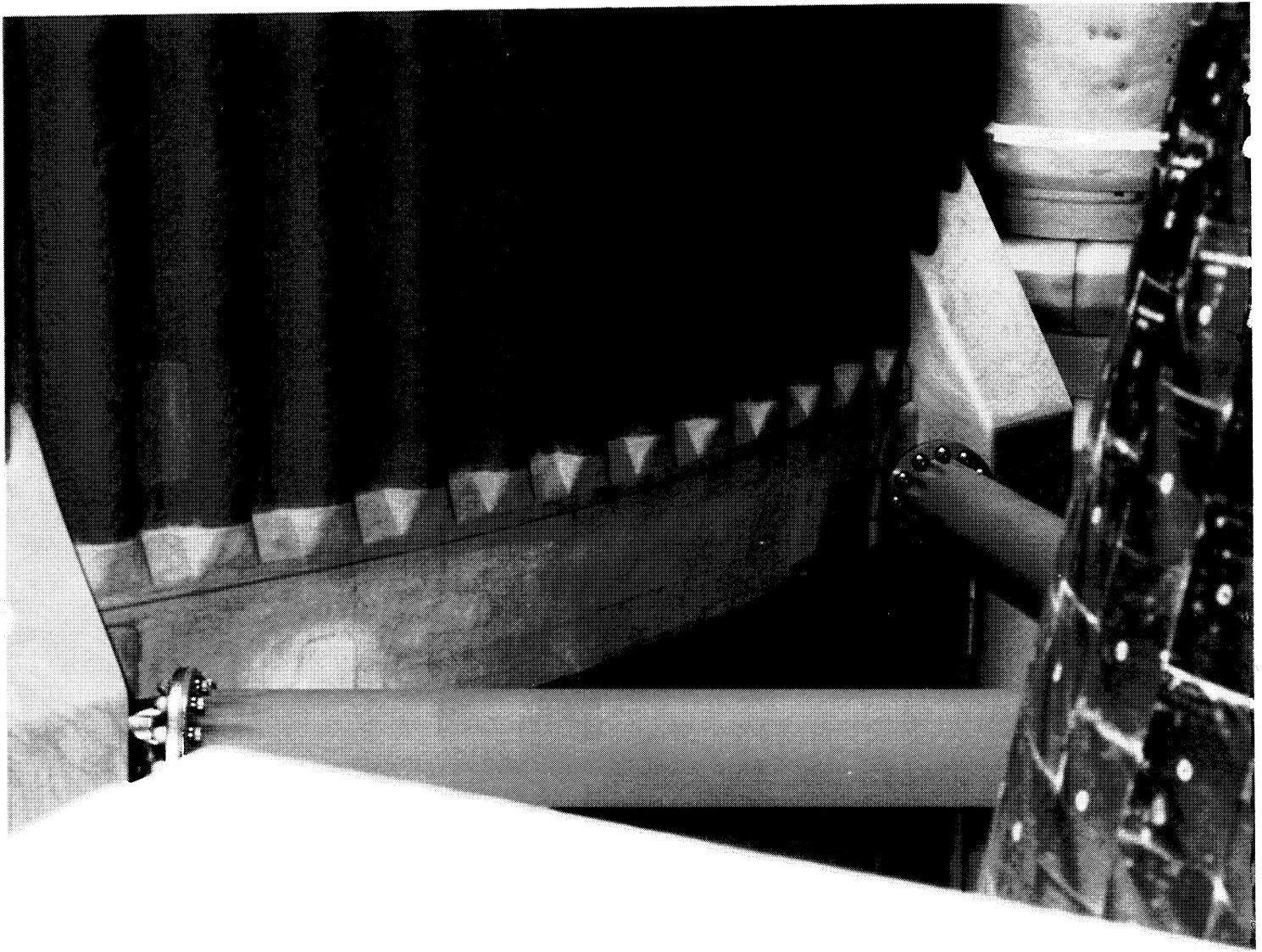


Photo 2: Bipod Jack Pad Closeouts

View of ET bipod jack pad closeouts prior to cryoload





Photo 3: Overall View of STS-65 Vehicle

OV-102 Columbia (17th flight), ET-64 (LWT 57), and BI-066 SRB's





Photo 4 : Overall view of SSME cluster



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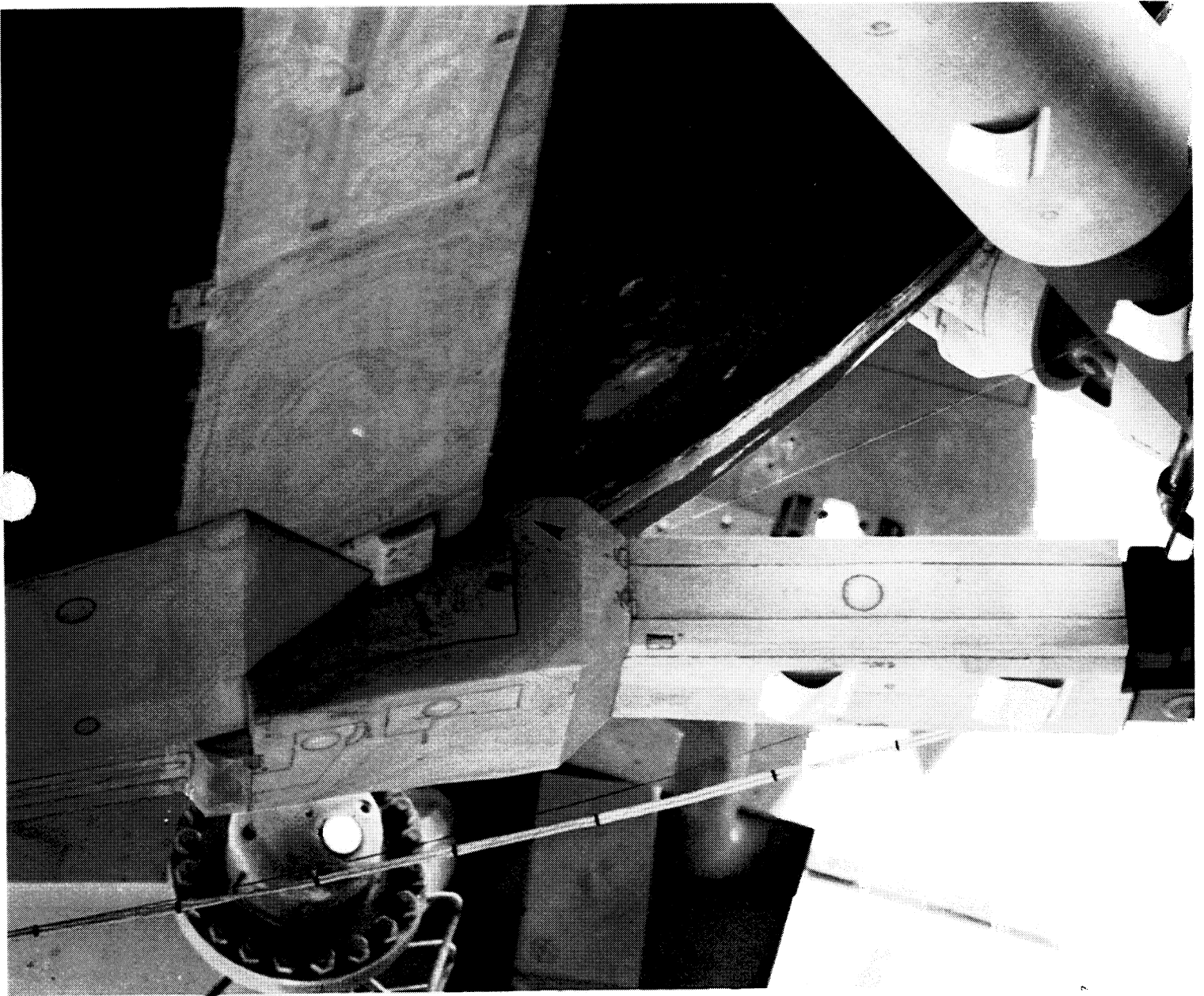


Photo 5 : Stress relief crack in -Y vertical strut cable tray TPS



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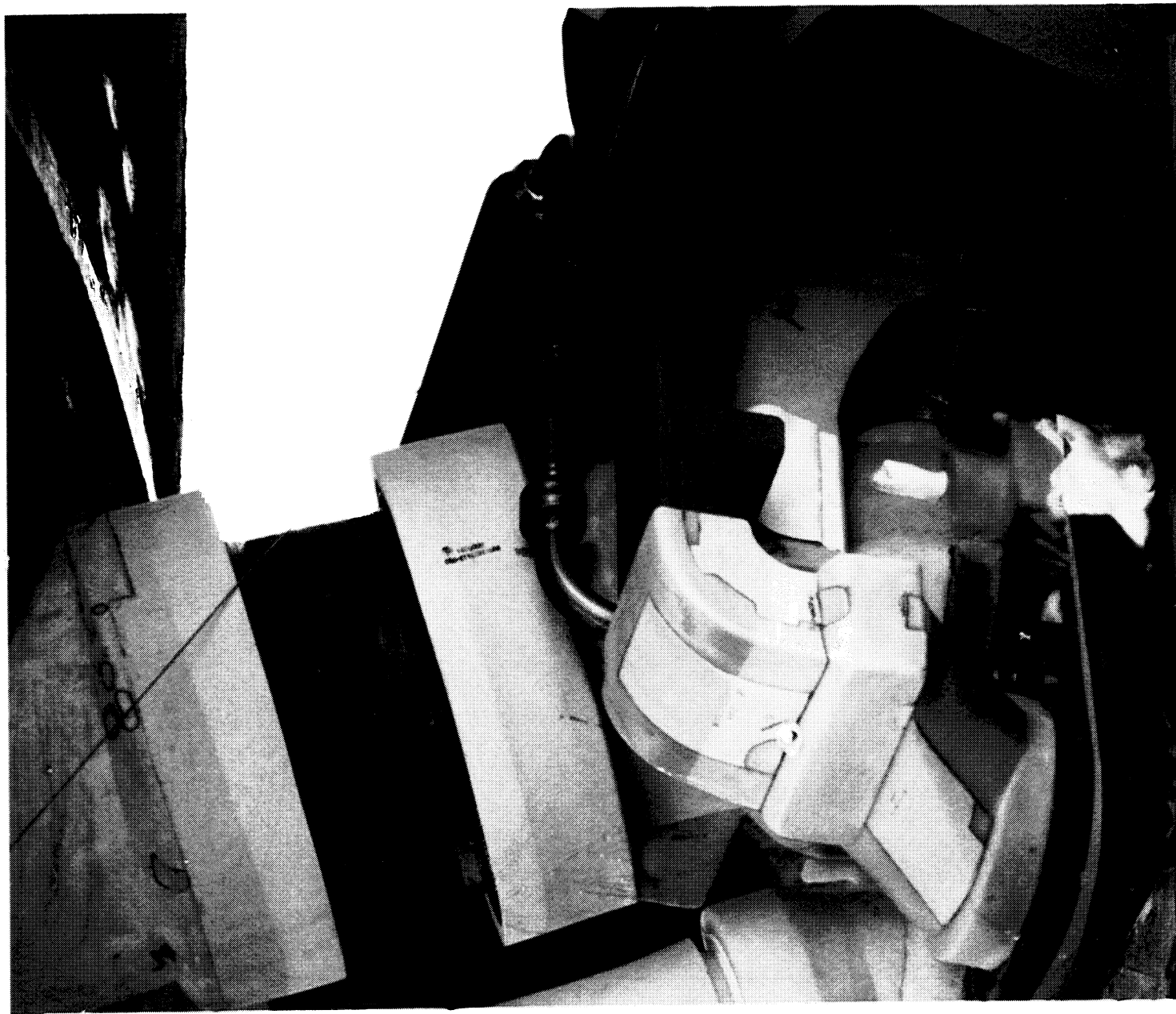


Photo 6 : LH2 ET/Orbiter umbilical

Less than usual ice/frost had formed on the umbilical during cryoload



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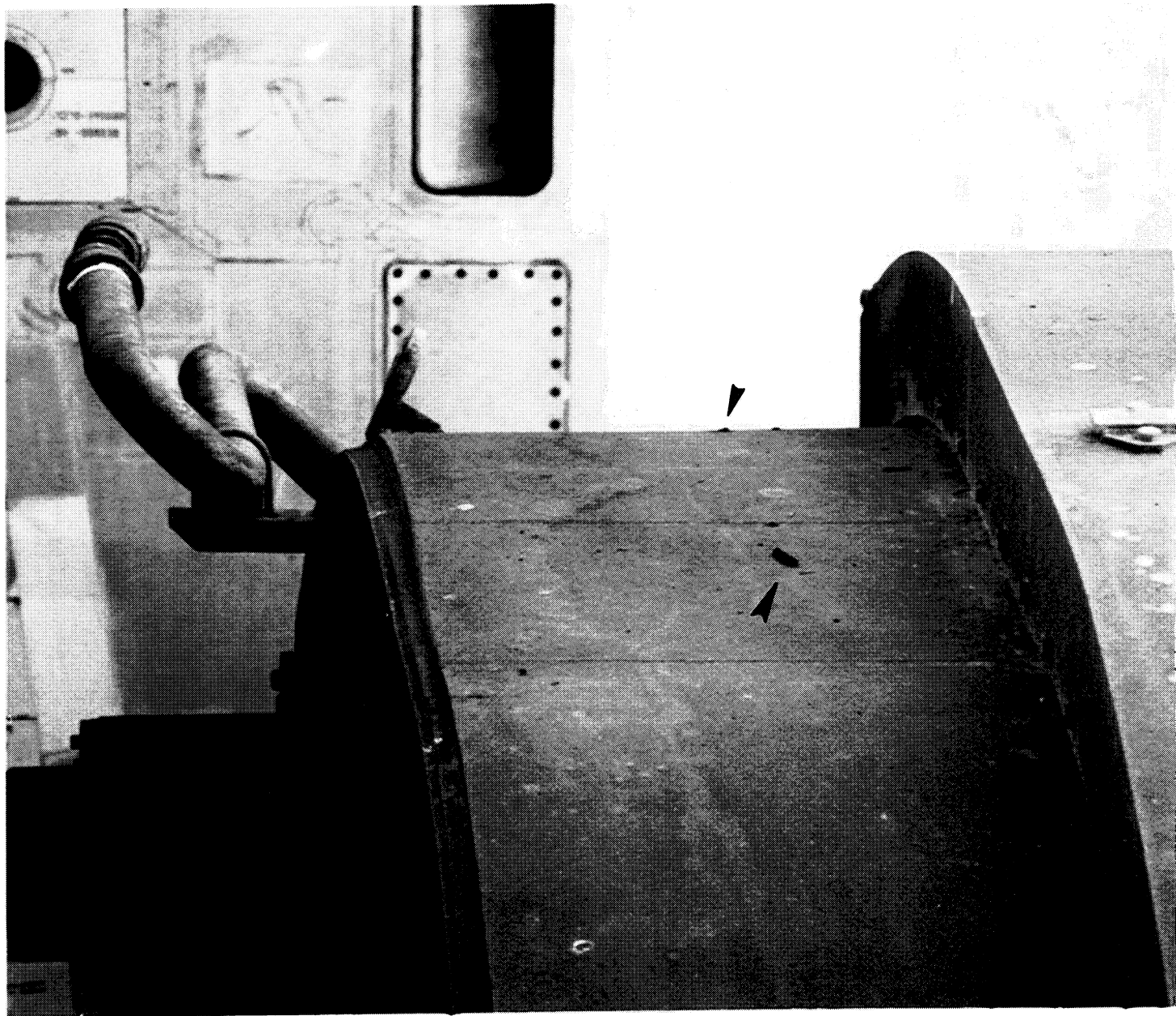


Photo 7 : Debris on top of LH2 TSM

Pen cap and washer/retainer from Orbiter 50-1 door closout were removed



4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, and RSS was conducted on 8 July 1994 from Launch + 2 to 4 hours.

No flight hardware or TPS materials were found.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. There was no visual indication of a stud hangup on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was normal and there were no burn-throughs. The SRB aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent arm appeared undamaged with the exception of a loose thermal blanket on the GOX vent hood.

The GH2 vent line was latched on the seventh tooth of the latching mechanism, had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound.

The new ECLSS building constructed adjacent to the FSS sustained severe roof damage from the launch. Pieces of sheet metal lay on the pad near the building, below the RSS, in the field west of the pad near the box cars and against the facility cooling tower.

Minor, but typical, pad damage included a broken camera lens cover at the northeast corner of the MLP, a deformed phone box door on the FSS 135 foot level, a 6 inch by 2 inch U-bolt plate separated from the GN2 purge line on the FSS 205 foot level, an OIS cap found on the intertank access structure grating FSS 215 foot level and a missing cap from an ECS duct on the FSS 215 foot level.

Debris inspections of the pad acreage, beach, and areas outside the pad perimeter were performed. No flight hardware or TPS material was found.

Post launch pad inspection anomalies are listed in Section 9.0.





Photo 8 : Post launch condition of north holddown post



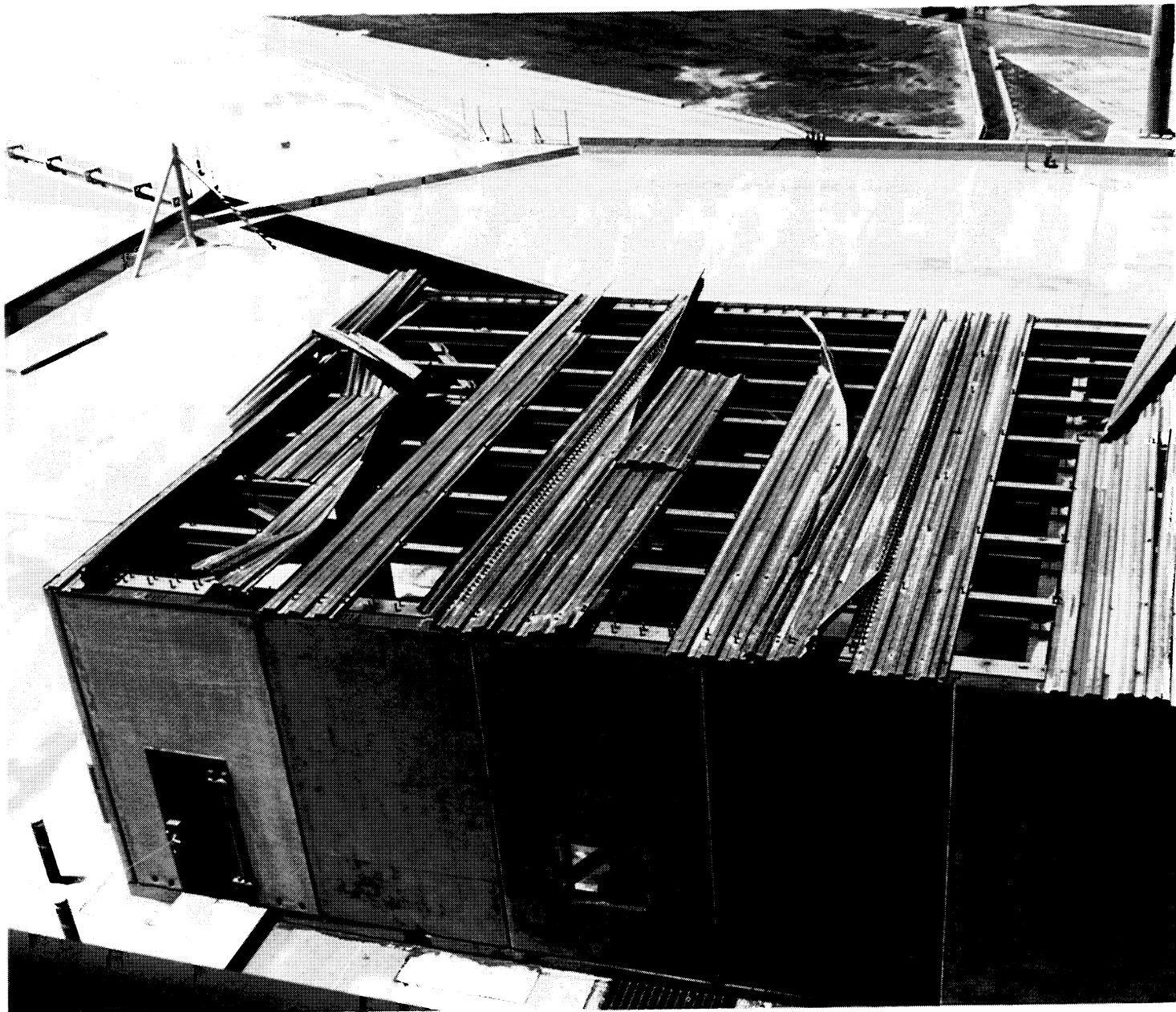


Photo 9 : Post launch damage to new ECLSS building

Damage to the sheet metal roof was caused by a combination of SRB plume and wind out of the east as the vehicle cleared the tower. The sheet metal will be replaced with concrete prior to the next launch.



5.0 FILM REVIEW AND PROBLEM REPORTS

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or In-Flight Anomalies were generated as a result of the film review. Post flight anomalies are listed in Section 10.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 102 films and videos, which included forty-one 16mm films, nineteen 35mm films, four 70mm films, and thirty-eight videos, were reviewed starting on launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission.

SSME ignition, Mach diamond formation, and gimbal profile appeared normal (OTV 151, 170, 171, E - 2, -3, -19, -20).

Fore-and-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster occurred during engine start-up. The motion was similar to that observed on previous launches (E-77).

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. Some pieces of ice contacted the umbilical cavity sill and were deflected outward, but no tile damage was visible (OTV 109, 163).

Surface coating material was lost from base heat shield tiles outboard of SSME #3 (1 place), righthand OMS pod (1 place), righthand ACPS stinger (1 place) and aft surface of lefthand ACPS stinger (2 places) (E-17, -18, -20).

A white, flexible object, most likely an RCS paper cover, first appeared in the SSME exhaust area moving towards the TSM and was eventually pulled into the plume by aspiration (E-2). RCS paper covers caused flashes in SSME #1 and #3 plumes during engine startup and lift-off

Numerous paint flakes fell from the sound suppression water pipe at SSME ignition (E-11).

Residual gaseous oxygen vapors exited the louvers after the GOX vent hood was retracted. ET "twang" was approximately 30 inches before returning to the 10-inch mark at liftoff (E-79).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150). GUCP disconnect from the ET was normal (E-33). Small ice particles, but no TPS, fell from the interface area after disconnect. The GH2 vent line appeared to latch properly (OTV 104, 160, E-41, -42, -50). Although there was no excessive slack in the static retract lanyard, a section of the cable contacted the GUCP legs during retraction. Post launch inspection found the GH2 vent line latched on the seventh tooth of the latching mechanism.

No stud hang-ups occurred on any of the holddown posts. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes. All north holddown posts doghouse blast covers closed normally.

One piece of thermal curtain tape was loose prior to lift-off (E-10, -15).

A light colored, flexible object, possibly a sound suppression water trough cloth parts tag, appeared in the field of view at 16:43:02.579 GMT (E-25).

Numerous light-colored objects, most likely SRB throat plug material, appeared out of the SRB flame trench (OTV 160).

Very light vapors on the -Z side of the External Tank near both SRB's were visible at approximately T+26 seconds. The vapors were most likely caused by light condensate on the ET prior to liftoff and/or water from the ET intertank access structure prelaunch firex flow wetting the tank prior to T-0 (E-57, -224).

Light colored debris aft of the LH inboard elevon at T+29 seconds was most likely pieces of thruster nozzle paper covers from the forward RCS (E-54, -213, -220).

A debris object falling aft of the vehicle at T+49 seconds MET may have been the loose piece of SRB thermal curtain tape observed on the RH SRB prior to liftoff (E-212, 223).

All SSME Dome Mounted Heat Shield closeout blankets appeared to be intact and missing no material.

Body flap movement (amplitude and frequency) was similar to previous flights (E-220).

Localized flow condensation occurred on numerous parts of the vehicle for a longer than usual period of time during ascent (E-207, -208, -213, -223, -224).

A white vapor cloud formed at T+57.485 seconds MET as the vehicle passed through a layer of atmospheric moisture (TV-5, -13, 21A; E-213, -222). The vehicle was traveling Mach 1.3 at an altitude of 34,000 feet (approximately). The vapor cloud was an aerodynamic induced phenomenon associated with the atmospheric conditions at that time. Similar occurrences of vehicle induced atmospheric condensation have been observed on past flights (STS-48 and -54) and is not considered a vehicle anomaly.

Exhaust plume recirculation, ET aft dome charring, and SRB separation appeared nominal. Numerous pieces of slag dropped out of the SRB plume before, during, and after separation.

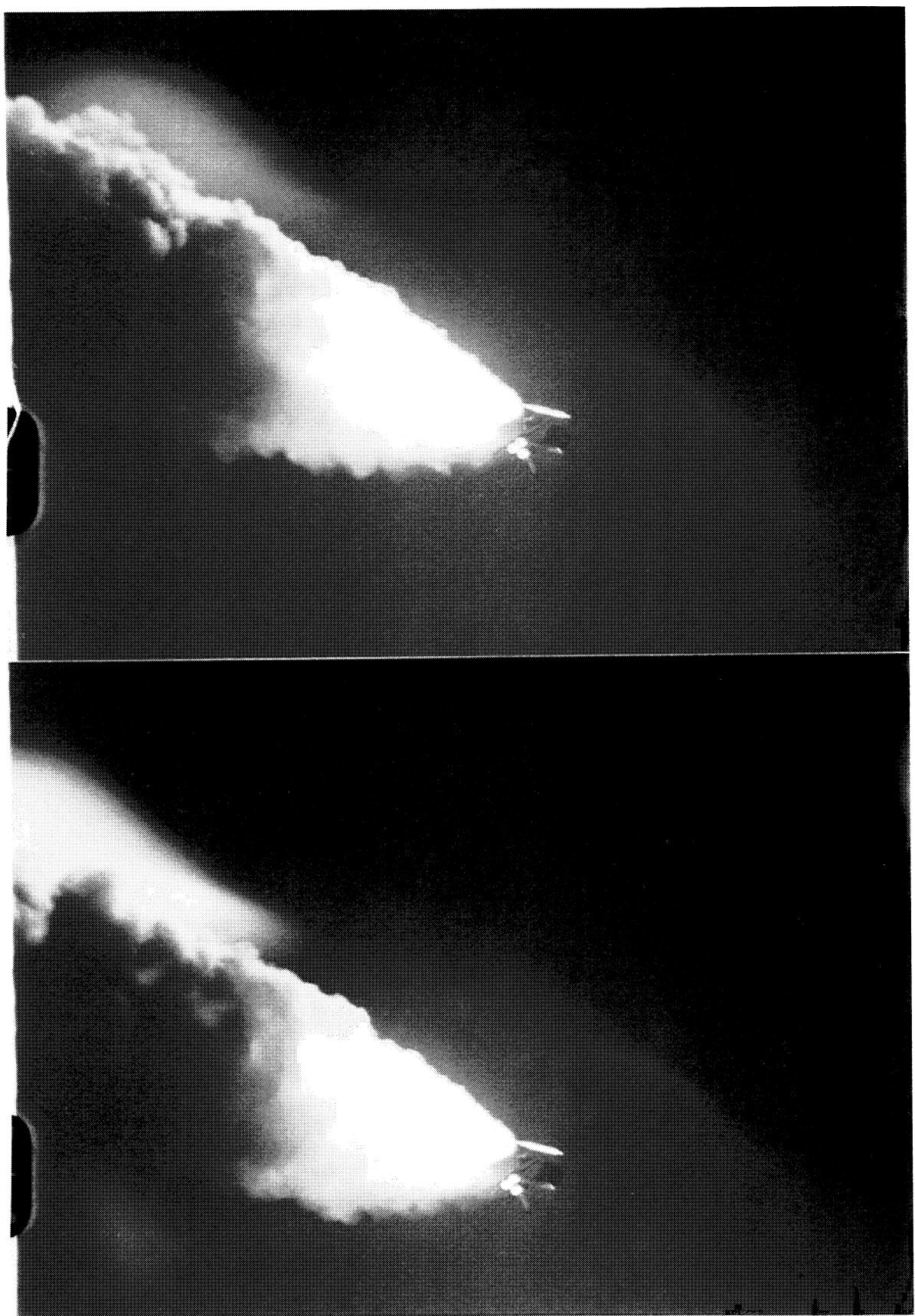


Photo 10 : Vapor cloud at T+58 sec. MET

A white vapor cloud formed aft of the vehicle along the flight path and was an aerodynamic induced phenomenon associated with atmospheric conditions at that time

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. Thirty-eight hand-held still images were obtained of the ET after separation from the Orbiter. OV-102 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. Data was obtained from all sources.

No major vehicle damage or lost flight hardware was observed that would have been a safety of flight concern. Review of the on-orbit photography resulted in no IFA candidates.

SRB separation from the External Tank was nominal. During SRB separation, a cluster of at least five pieces of TPS appeared to originate behind the LH2 ET/ORB umbilical cable tray or clam shell closeout (frame 1047). The pieces were moving forward and contacted adjacent umbilical TPS surfaces. One of the pieces was later identified falling aft. A piece of foam, approximately 12 inches by 8 inches by 1 inch, appeared to originate from the aft surface of the LH2 ET/ORB umbilical cable tray (frame 1103). Loss of TPS this thick may have exposed substrate.

ET separation from the Orbiter was nominal. The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, LO2 tank acreage, PAL ramps, RSS antennae, flight door, bipod ramps, LO2 feed line, and aft hard point. Erosion of the manhole cover closeouts and aft dome apex was also typical.

Two divots, 6 to 8 inches in diameter, were present in the LH2 tank-to-intertank flange closeout immediately to the +Y side of the PAL ramp. Both divots went to substrate and exposed the primer.

Three shallow "popcorn" type divots were visible in stringer valleys on the +Z intertank acreage just forward of the +Y bipod.

A divot, 6 inches in diameter but shallow in depth, occurred in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout between the right (+Y) bipod spindle housing closeout and the LO2 feedline support bracket (XT-1129).

Both bipod jack pad closeouts were intact and appeared to be in excellent condition.

LO2 feedline flange closeouts exhibited minor erosion. A small divot occurred in the pressurization line ramp at stations XT-1152 and -1787.

The LH2 ET/ORB umbilical appeared to be in good condition with the exception of foam peeled back on the side of the umbilical near the forward inboard and outboard pyro canister closeouts. The red purge seal was intact. Blistering of the fire barrier coating was typical. Frozen hydrogen adhered to the 17-inch flapper valve. Foam was missing or eroded from the vertical section of the cable tray, the LH2 feedline outboard support bracket, and the aft surface of the -Y vertical strut.



2

Foam on the forward inboard corner of the LO2 ET/ORB umbilical appeared slightly damaged. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. The red purge seal was intact. Although not definitive in the film, the lightning contact strip across the forward part of the umbilical and as many as three of the four smaller lightning contact strips may be missing. A light colored debris object floating near the crossbeam may be the large contact strip.

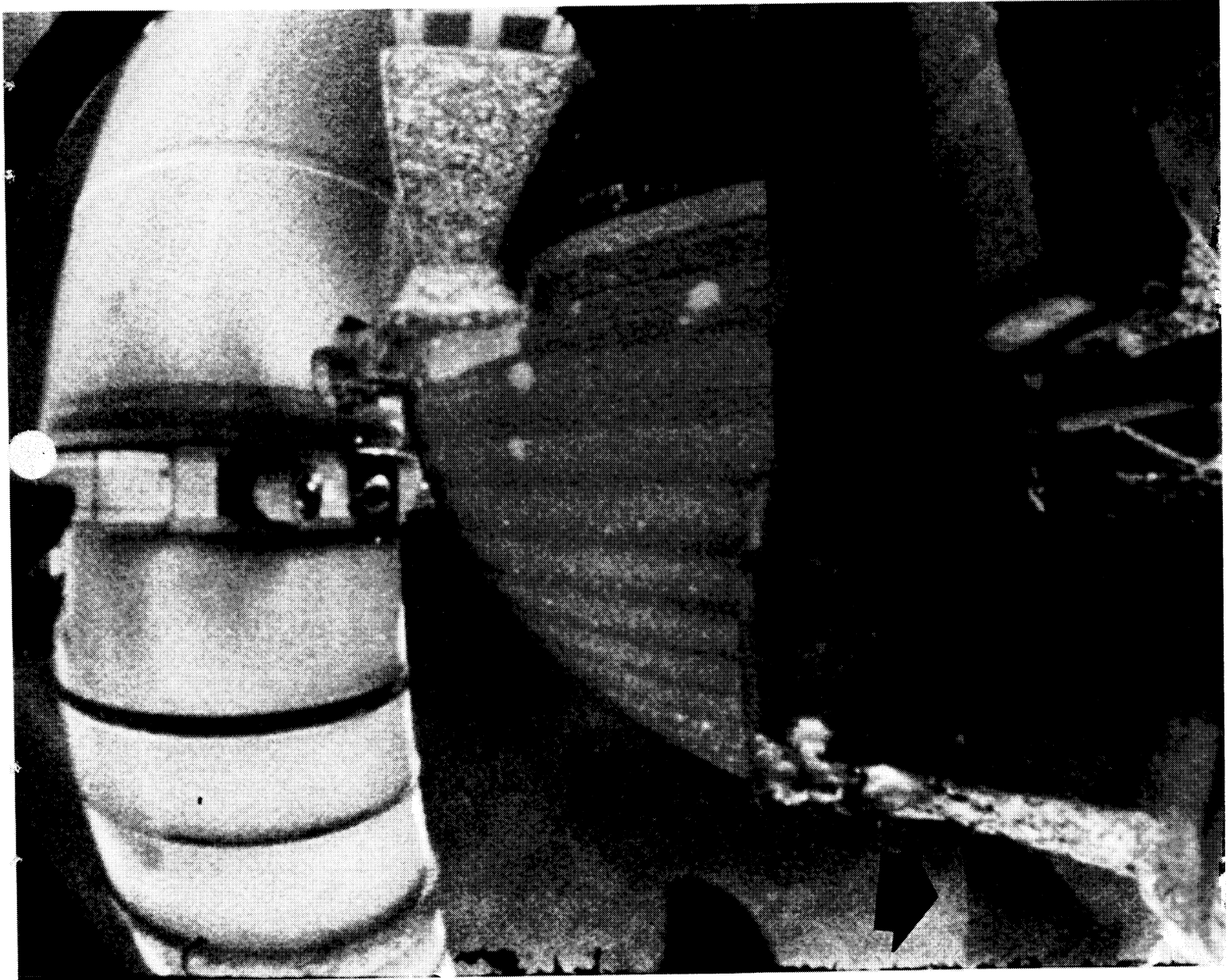


Photo 11 : SRB separation from External Tank

Structural separation of the SRB's from the External Tank appeared nominal. A piece of foam, approximately 12 inches by 8 inches by 1 inch, appeared to originate from the aft surface of the LH2 umbilical cable tray (arrow). Loss of TPS this thick may have exposed the substrate.



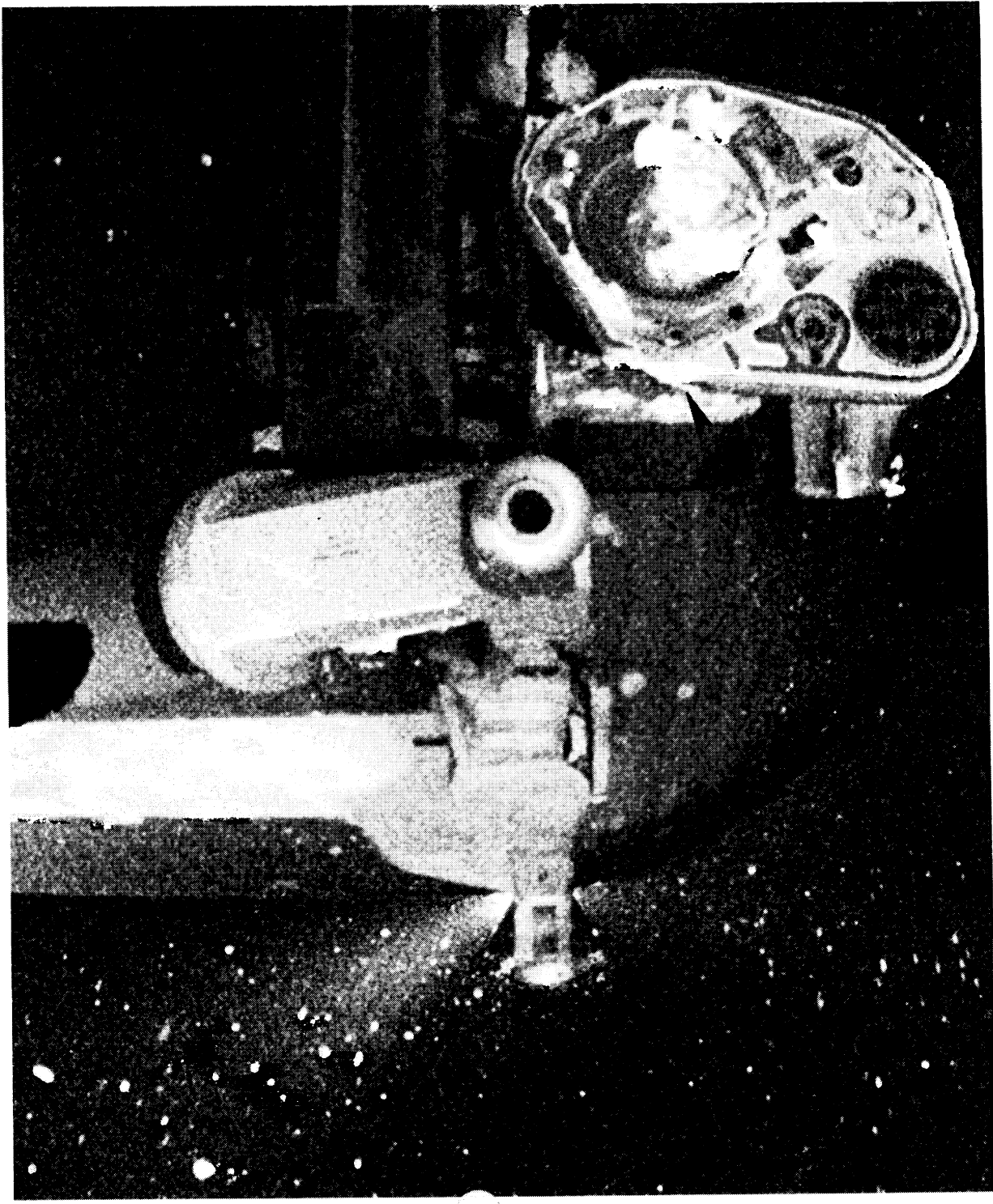


Photo 12 : LH2 ET/Orbiter umbilical after separation.

Structural separation of the ET from the Orbiter appeared nominal. Foam was peeling back on the side of the umbilical near the forward inboard and outboard pyro canister closouts. The white spot on the ET near the XT-2058 ring frame is ice/frost that formed near the TSE fitting.



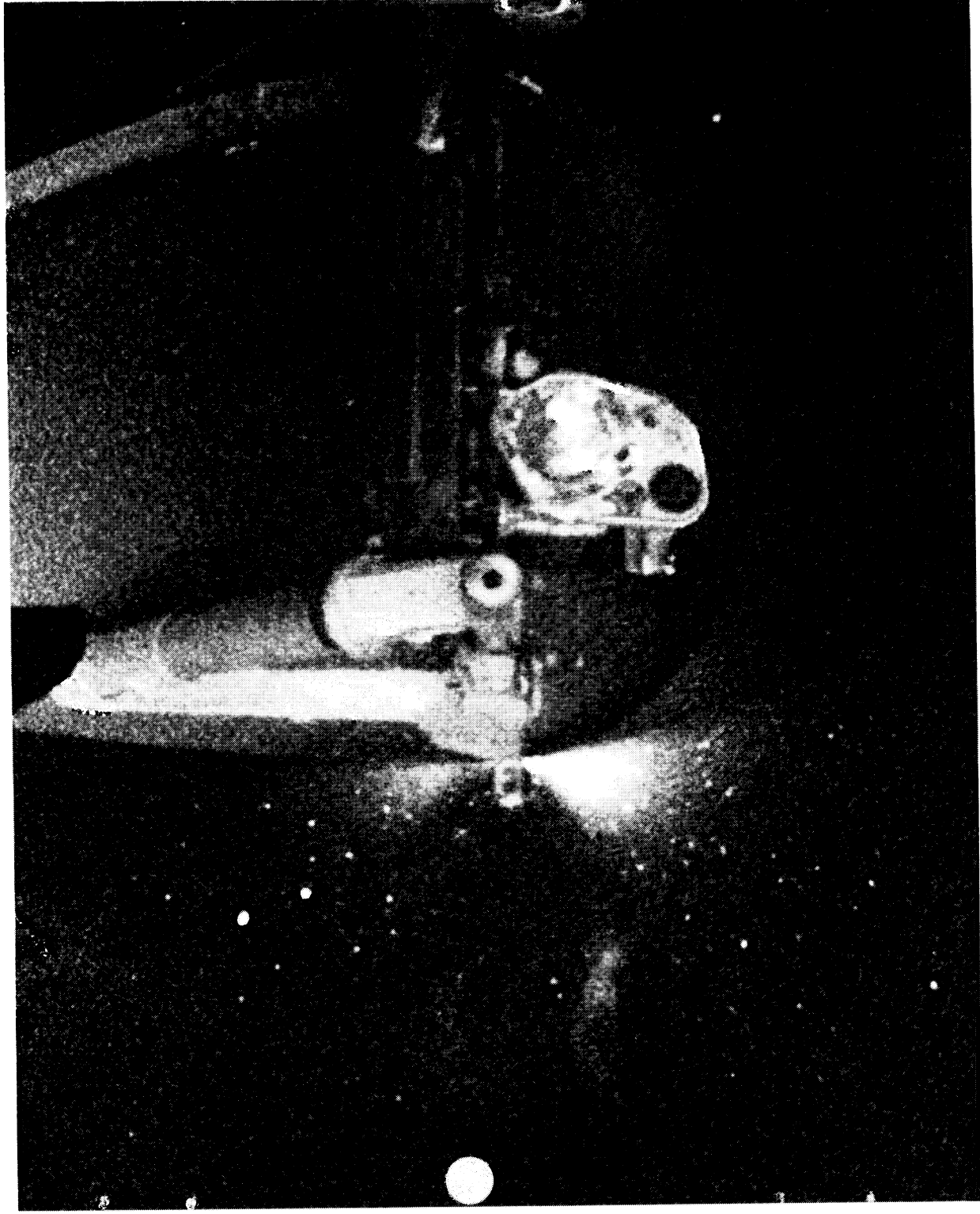


Photo 13 : On-orbit debris near External Tank

Light colored object drifting near the External Tank crossbeam may be a missing lightning contact strip from the forward section of the LO2 ET/ORB umbilical



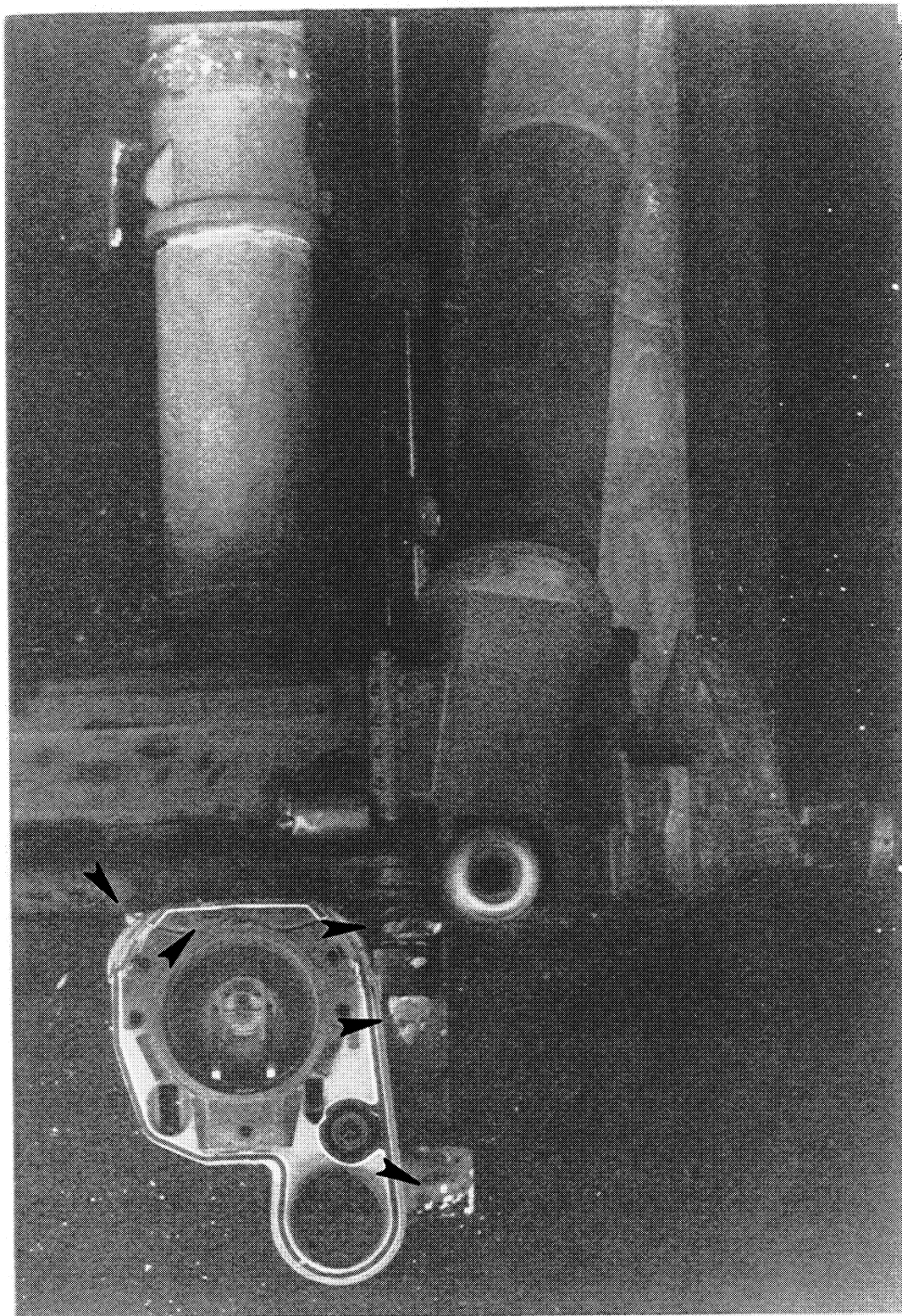


Photo 14 : LO2 ET/Orbiter umbilical after separation.

Foam on the forward inboard corner of the umbilical appeared slightly damaged. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. Although not definitive in the photographs, as many as four of the five lightning contact strips appeared to be missing from the interface plate.



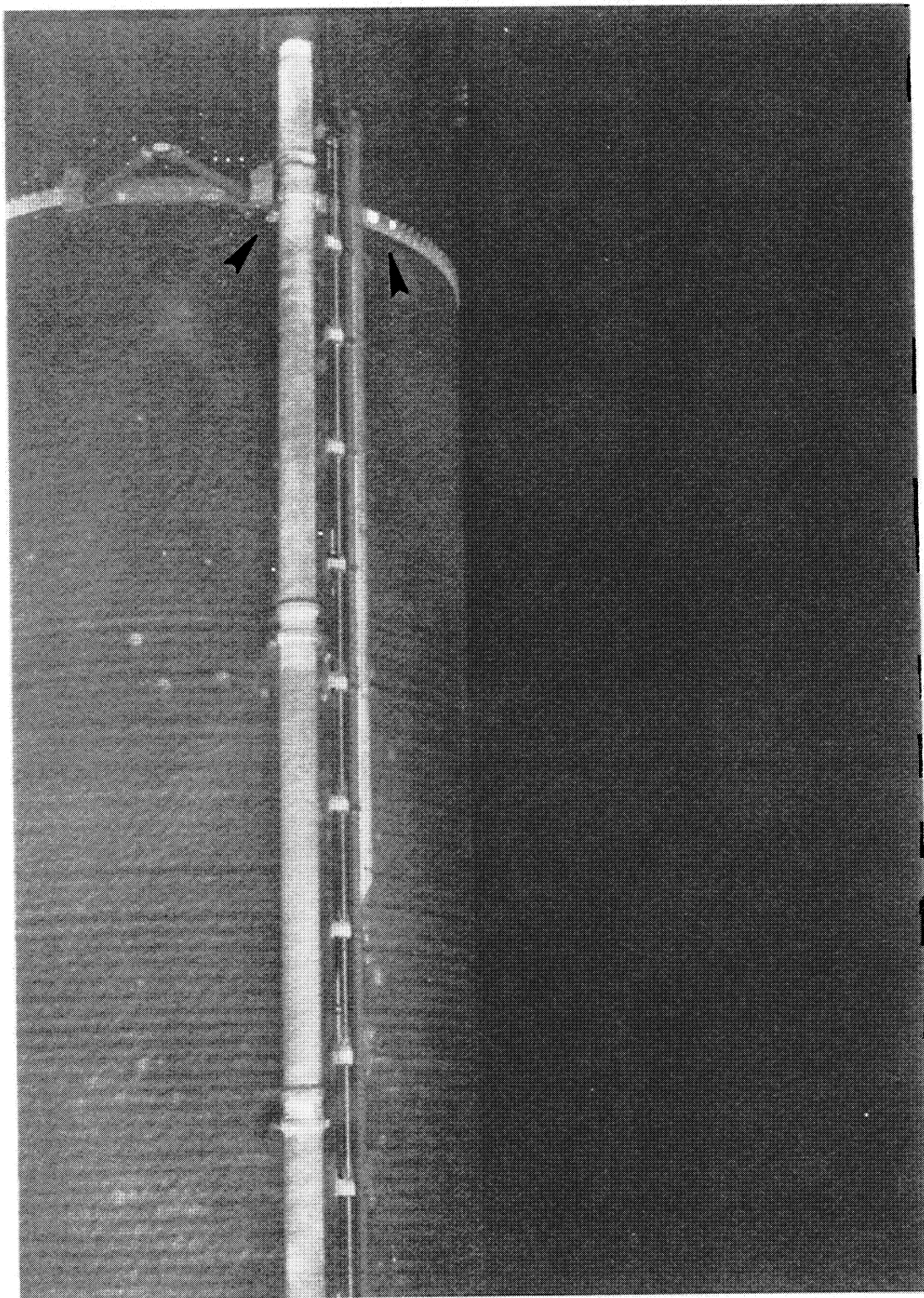


Photo 15 : On-orbit view of ET Intertank and Bipods

Two divots, 6 to 8 inches in diameter, were present in the LH2 tank-to-intertank flange closeout immediately to the +Y side of the PAL ramp. Both divots went to substrate and exposed the primer. A divot, 6 inches in diameter but shallow in depth, occurred in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout between the right (+Y) bipod spindle housing closeout and the LO2 feedline support bracket. Both bipod jack pad closeouts were intact and appeared to be in excellent condition.





Photo 16 : External Tank -Y side and aft dome after separation

The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the LO2 tank acreage, flight door, and LH2 tank -Y acreage. Erosion of the manhole cover closeouts and aft dome apex was also typical.



5.3 LANDING FILM AND VIDEO SUMMARY

A total of 26 films and videos, which included four 16mm high speed films, ten 35mm large format films and twelve videos, were reviewed after the 1 August 1994 landing at KSC.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared nominal. Wing tip vortices were very pronounced due to the amount of moisture in the air and the time of landing.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was almost simultaneous.

Pilot chute deployment appeared nominal though the chute risers were contacted by the drag chute door caught in aerodynamic vortices aft of the Orbiter. Function of the pilot chute was not affected and movement of the drag chute door did not threaten drag chute deployment, which appeared nominal. The drag chute was blown slightly eastward relative to the Orbiter during rollout.

Touchdown of the nose landing gear was smooth. No significant TPS damage was visible during rollout with the exception of ripped/torn SSME DMHS blankets.



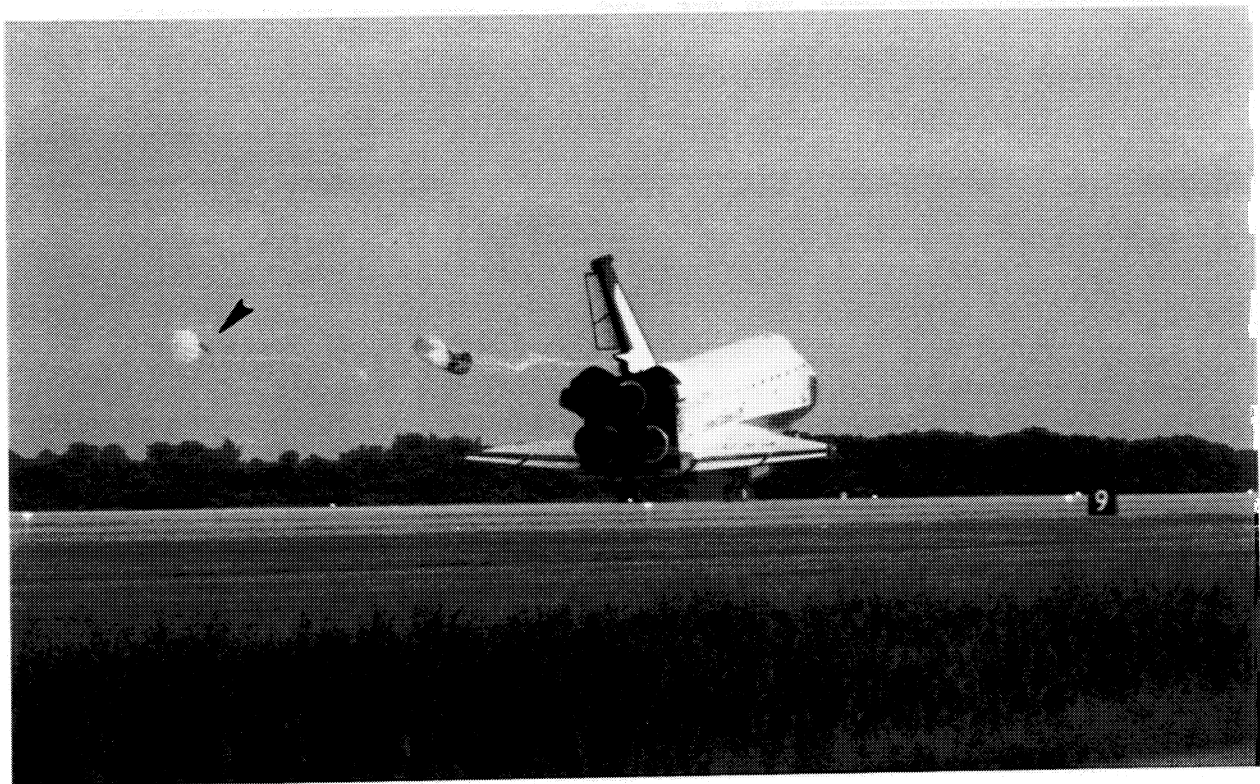
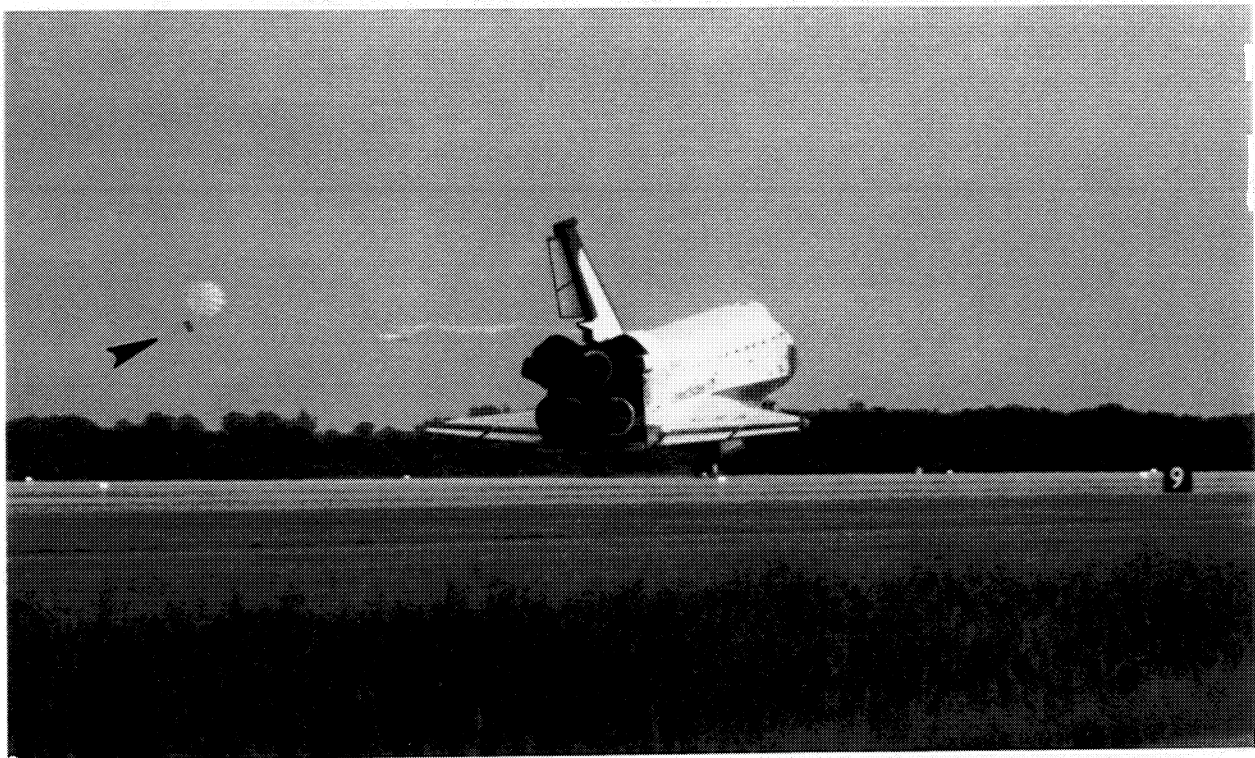


Photo 17 : Drag chute door contact with pilot chute during landing.

Pilot chute deployment appeared nominal though the chute risers were contacted by the drag chute door caught in aerodynamic vortices aft of the Orbiter. Function of the pilot chute was not affected and movement of the drag chute door did not threaten drag chute deployment, which appeared nominal.



6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 11 July 1994 from 1030 to 1230 hours.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had 24 MSA-2 debonds over fasteners. Two areas of missing TPS, 2"x1" and 1"x1" respectively, were located between the -Y and -Z axes and the 275 and 318 ring frames (Figure 1). Hypalon paint was blistered/missing along the 395 ring frame where BTA had been applied. Some of the underlying BTA was lightly sooted. The BSM aero heat shield covers had locked in the fully opened position.

The RH forward assembly exhibited no missing TPS but had one acreage debond aft of the flight door (Figure 2). Both RSS antennae covers/phenolic base plates were intact. Hypalon paint was blistered/missing over the areas where the BTA had been applied. The underlying BTA was not sooted. No pins were missing from the frustum severance ring.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. SRB stiffener rings were damaged by water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited typical delamination. Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered/missing over the areas where the BTA had been applied. K5NA was missing from the BSM nozzles.

The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. EPON shim material is no longer bonded to the HDP #3 and #4 aft skirt structure.

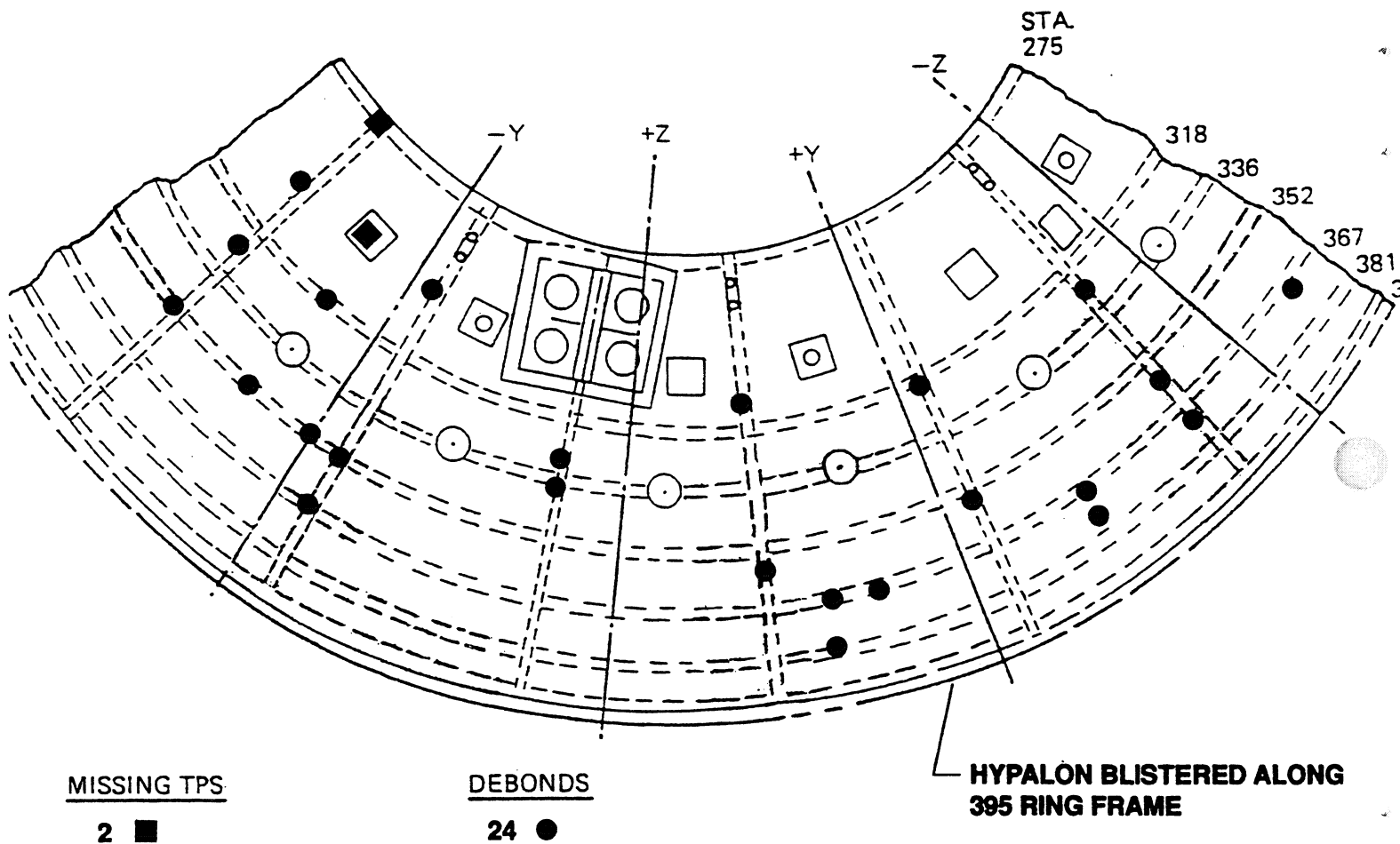
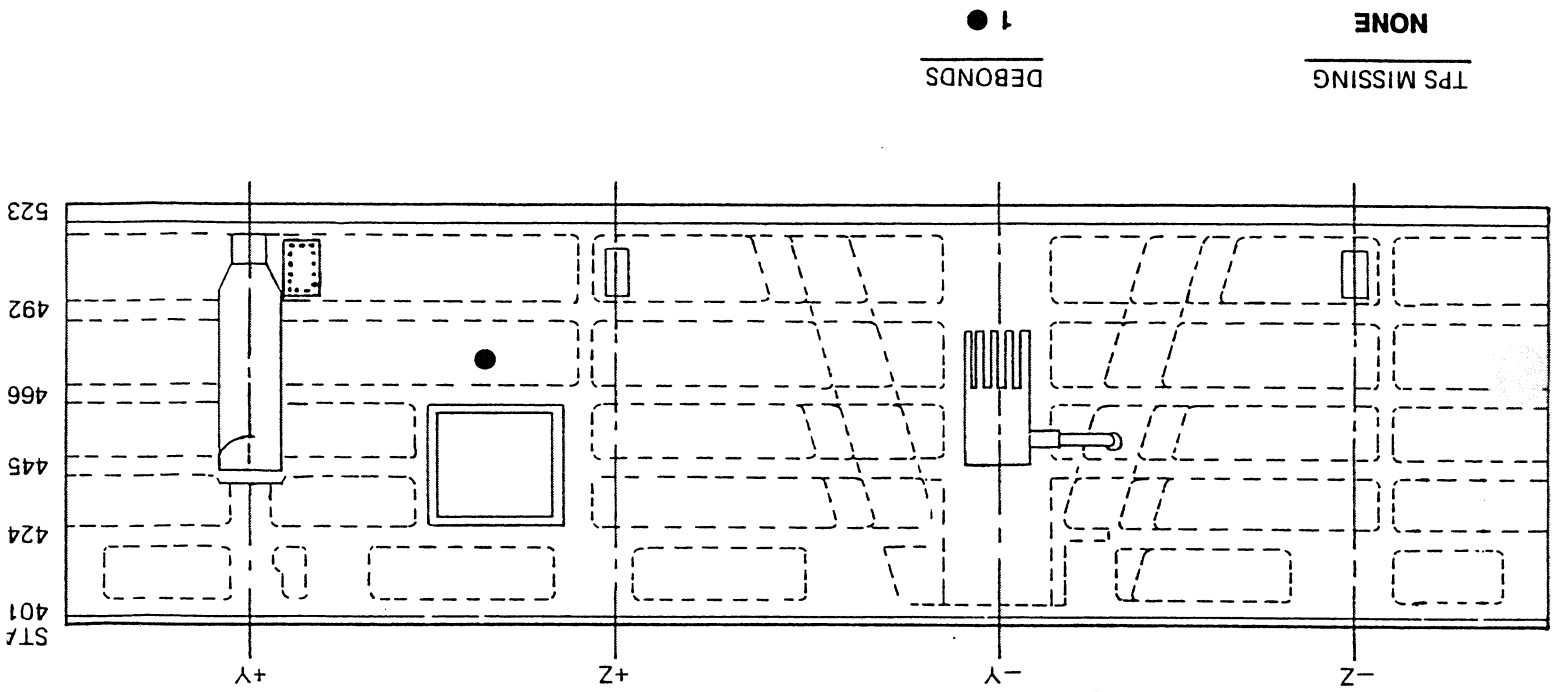


Figure 1 : RH SRB Frustum Debonds

Figure 2 : RH Forward Assembly Debonds





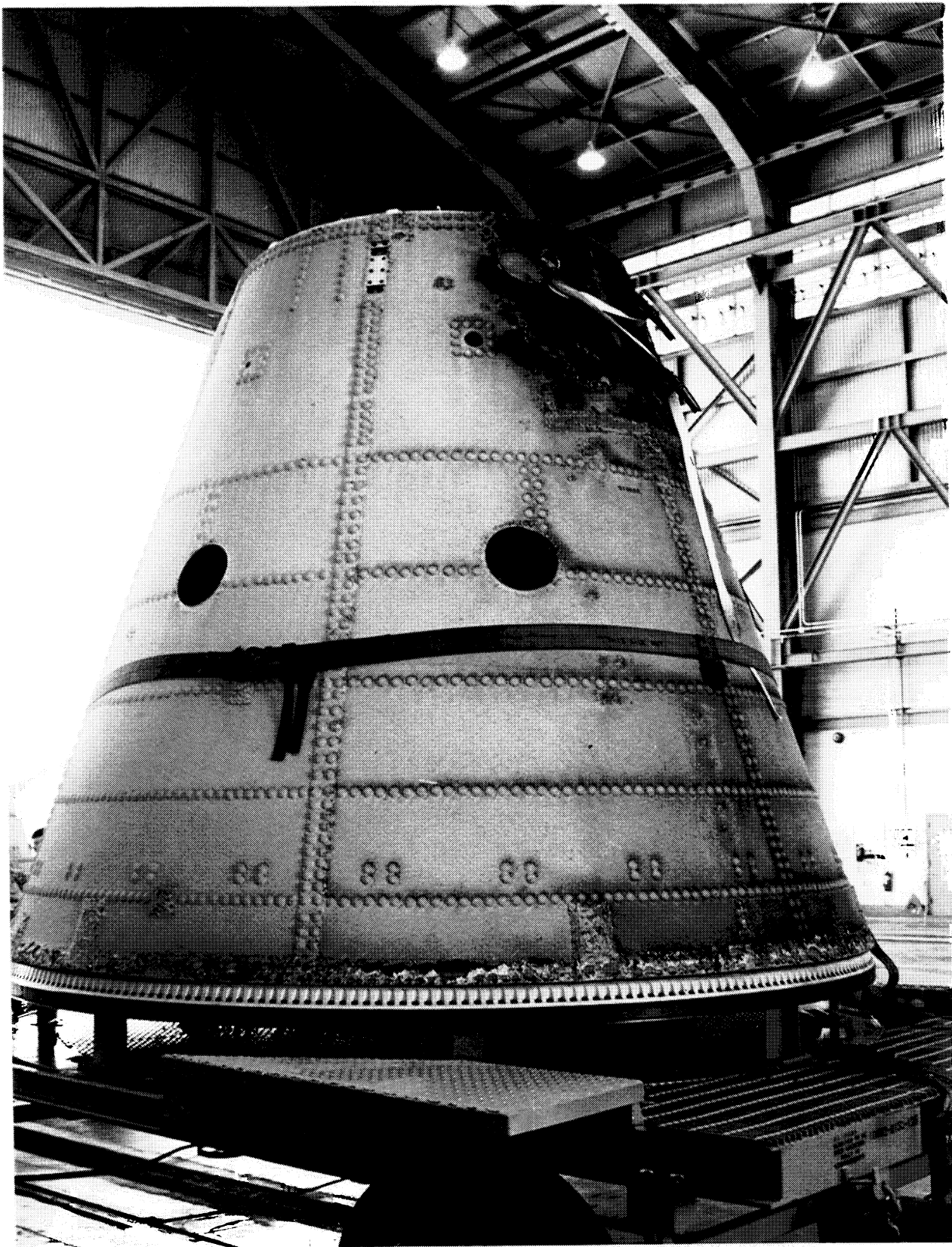


Photo 18 : RH SRB Frustum

The RH frustum had 24 MSA-2 debonds over fasteners. One of the two 2"x1" areas of missing TPS is visible between the 275 and 318 ring frames (arrow). The BSM aero heat shield covers had locked in the fully opened position.





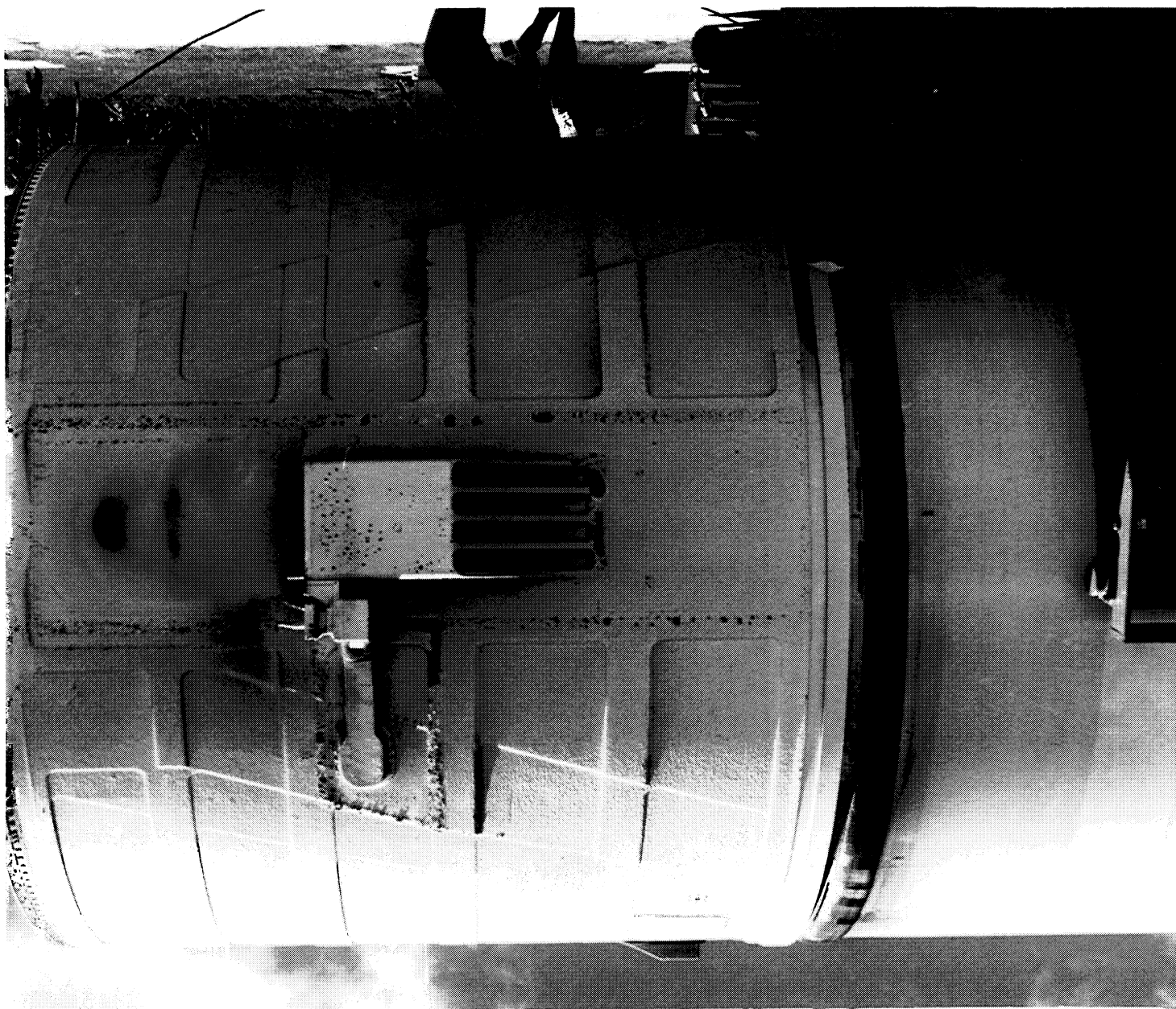
Photo 19 : Blistered/Missing Hypalon Paint

Hypalon paint was blistered/missing along the 395 ring frame where BTA had been applied. Some of the underlying BTA was lightly sooted.



Hypalon paint was blistered/missing where BTA closcouts had been applied

Photo 20 : RH Forward Assembly





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Photo 21 : RH Aft Booster / Aft Skirt

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. SRB stiffener rings were damaged by water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.



6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 11 MSA-2 debonds over fasteners. Hypalon paint was blistered/missing along the 395 ring frame where BTA had been applied. All BSM aero heat shield covers had locked in the fully opened position. However, the upper right cover was bent backward to the 90 degree position and the attach ring had been deformed by parachute riser entanglement (Figure 3).

The LH forward assembly acreage exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Blistering of the Hypalon paint occurred near the ET/SRB attach point. No pins were missing from the frustum severance ring.

The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. SRB stiffener rings were damaged by water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring was delaminated. Aft skirt acreage TPS was generally in good condition. However, three areas of MSA-2 were missing from fasteners near the 1894 ring frame between HDP #6 and #8 (Figure 4). Hypalon paint was blistered/ missing over areas where BTA had been applied. K5NA was missing from the BSM nozzles.

The Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. EPON shim material is no longer bonded to the HDP #7 and #8 aft skirt structure.

SRB Post Launch Anomalies are listed in Section 9.0.

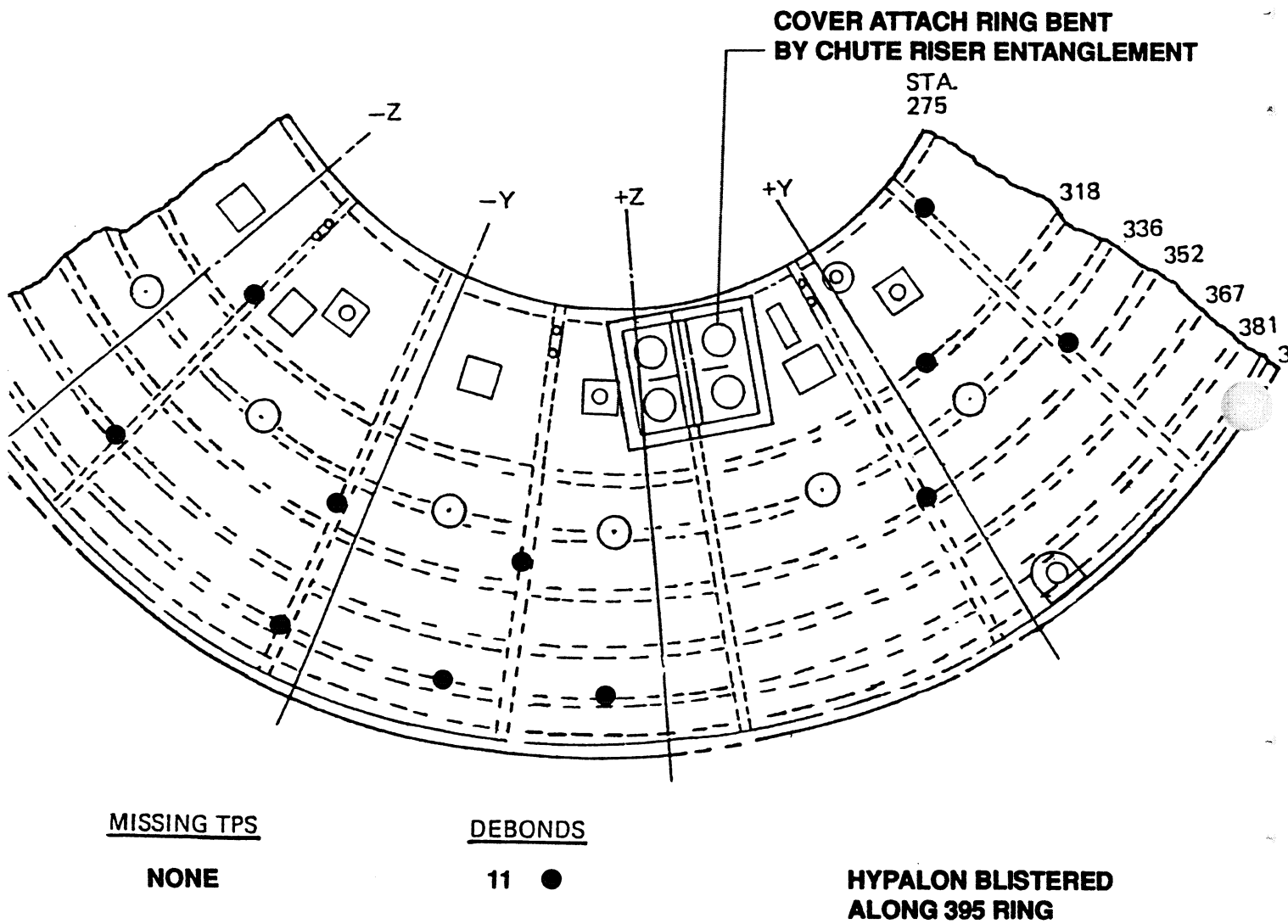


Figure 3 : LH Forward Frustum

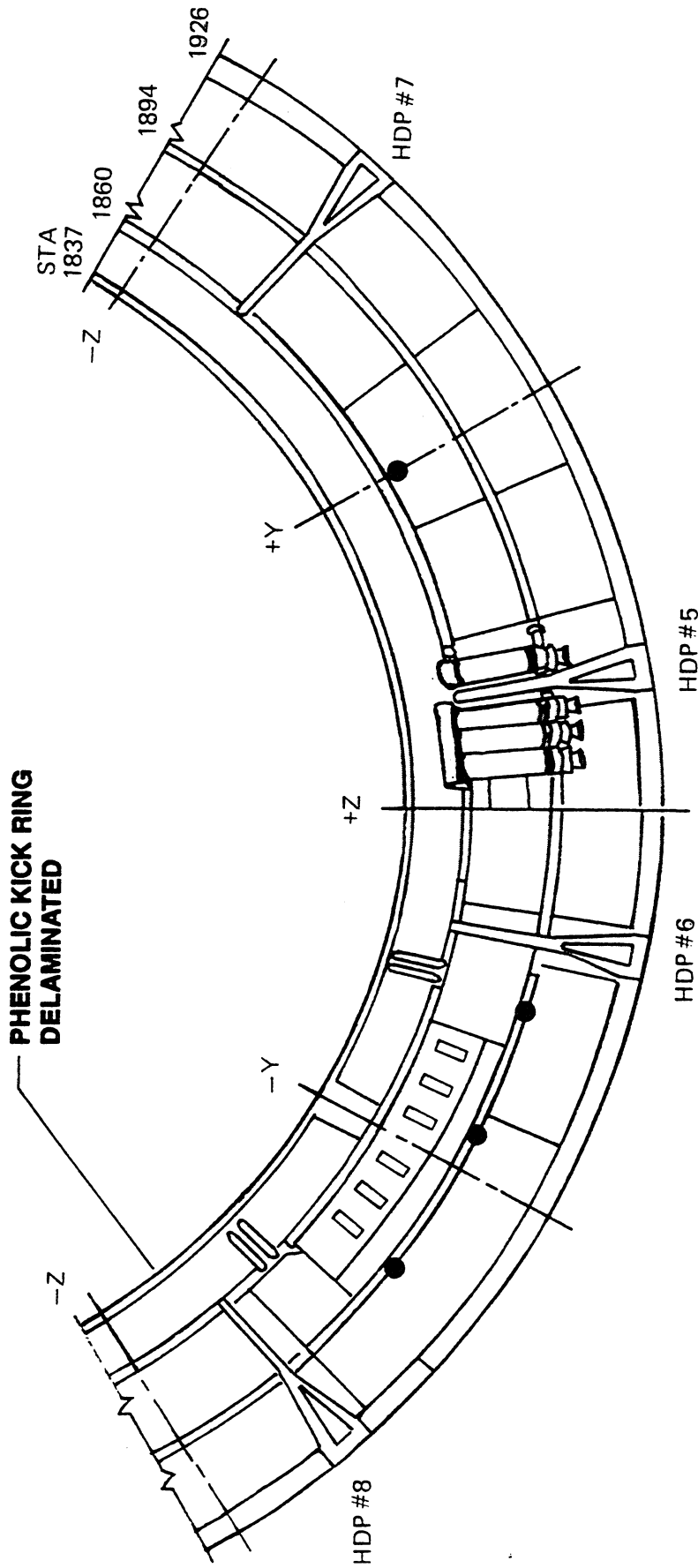


Figure 4 : LH Aft Skirt

ALL HDP DCS PLUNGERS
STEATED PROPERLY

4 ● AREAS OF MISSING TPS



1

2



3

4



5

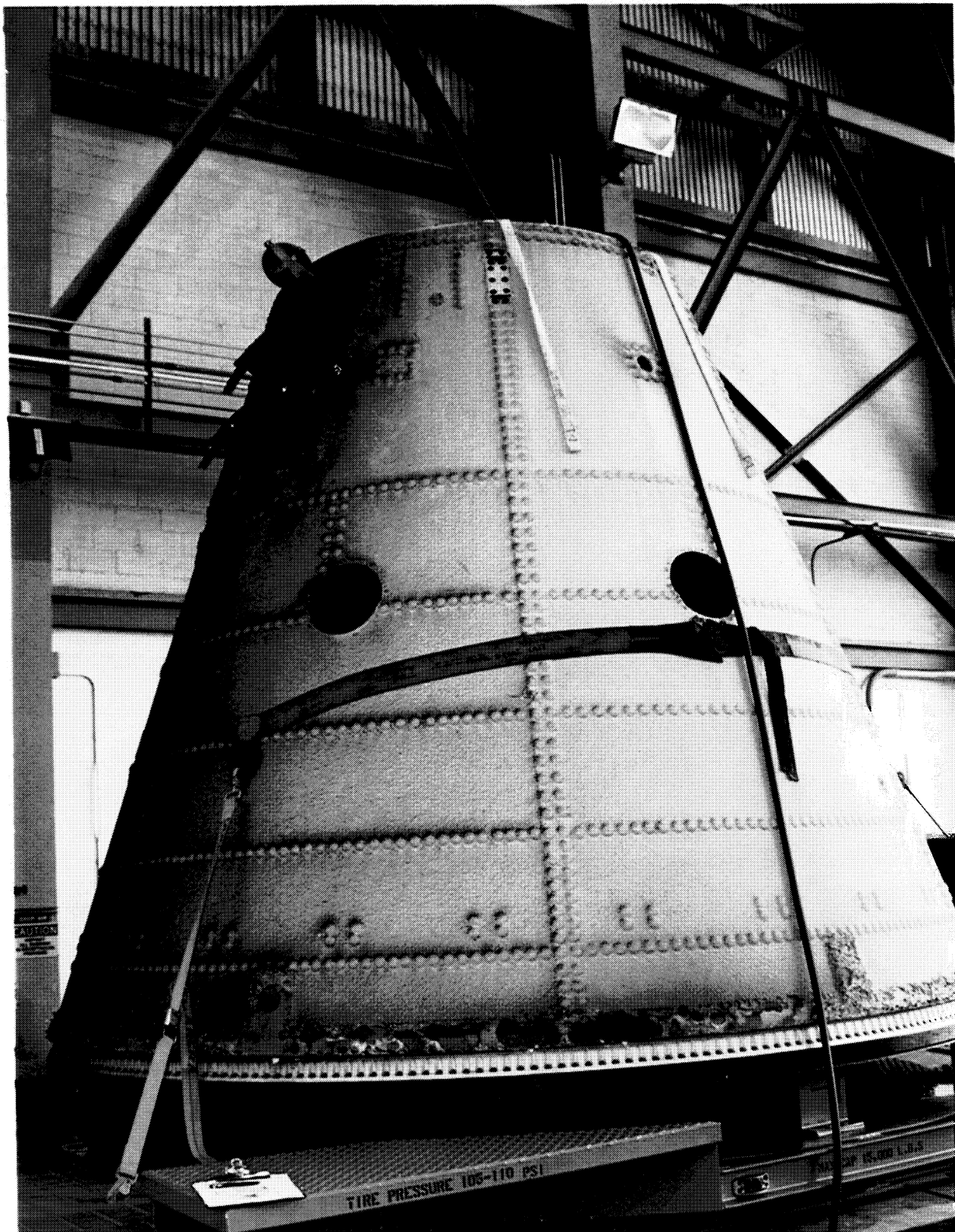


Photo 22 : LH SRB Frustum

The LH frustum was missing no TPS but had 11 MSA-2 debonds over fasteners.. All BSM aero heat shield covers had locked in the fully opened position. However, the upper right cover was bent backward to the 90 degree position and the attach ring had been deformed by parachute riser entanglement.

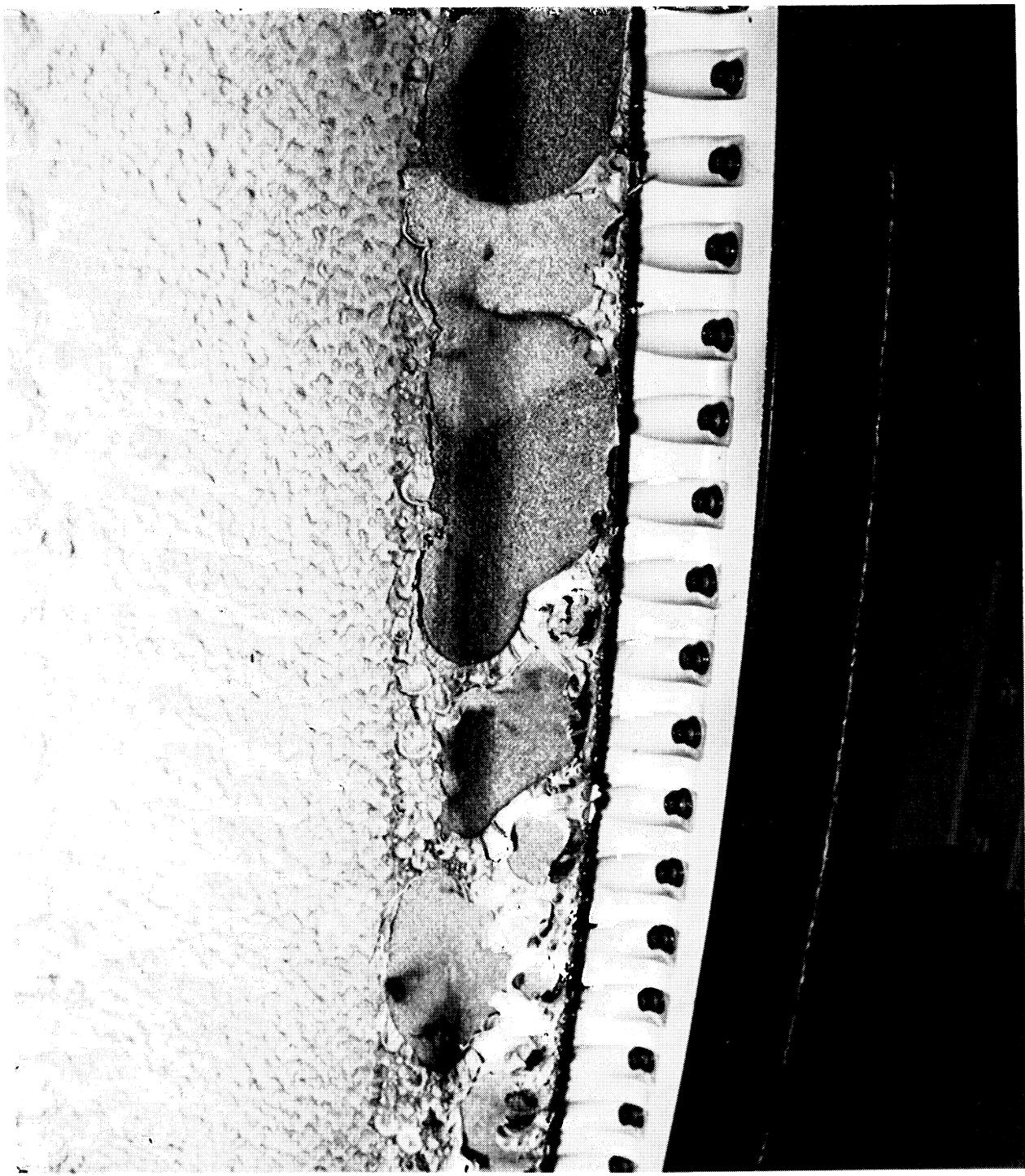


Photo 23 : Blistered/Missing Hypalon Paint

Hypalon paint was blistered/missing along the 395 ring frame where BTA had been applied



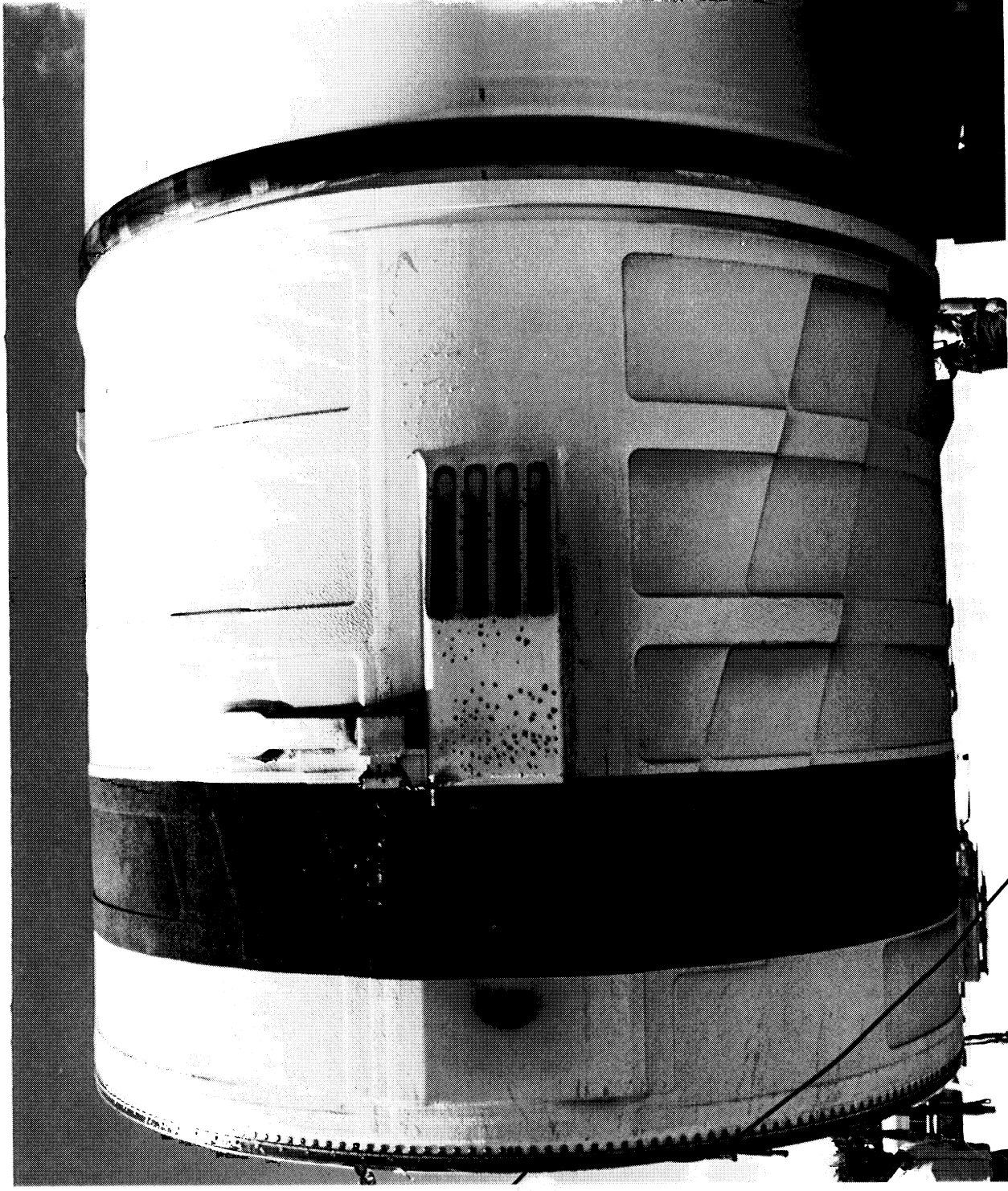


Photo 24 : LH Forward Assembly





Photo 25 : LH Aft Booster / Aft Skirt

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. SRB stiffener rings were damaged by water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.



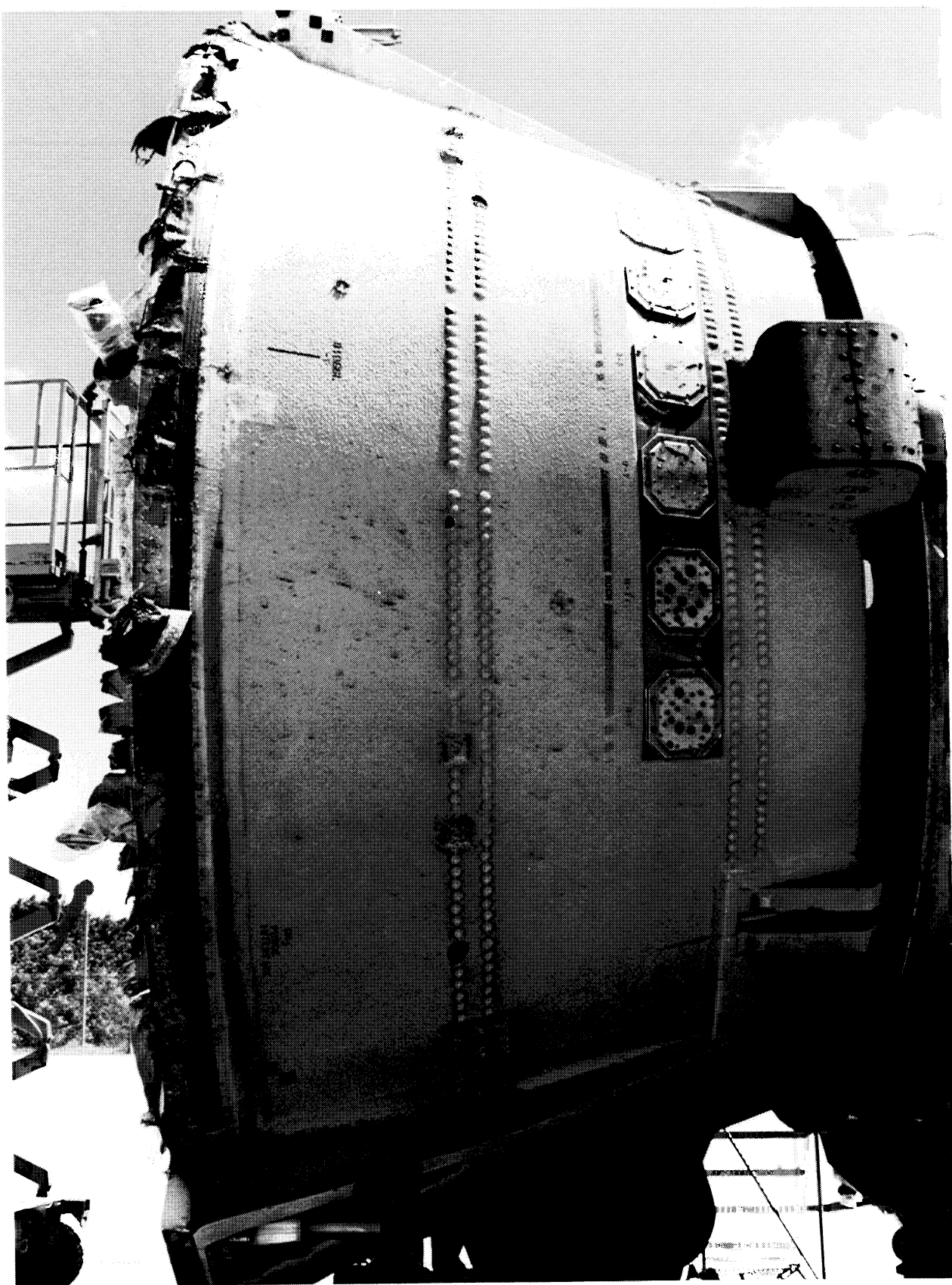


Photo 26 : Areas of missing TPS on LH aft skirt

Aft skirt acreage TPS was generally in good condition. However, three areas of MSA-2 were missing from fasteners near the 1894 ring frame between HDP #6 and #8. Hypalon paint was blistered/missing over areas where BTA had been applied.



7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-102 (Columbia) was conducted 23-24 July 1994 at the Kennedy Space Center on Shuttle Landing Facility (SLF) runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 151 hits, of which 21 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 47 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates the total number of hits was slightly above average and the number of hits 1-inch or larger was average (reference Figures 5-8).

The following table breaks down the STS-65 Orbiter debris damage by area:

	<u>HITS > 1"</u>	<u>TOTAL HITS</u>
Lower surface	17	123
Upper surface	2	13
Right side	0	3
Left side	0	3
Right OMS Pod	0	2
Left OMS Pod	2	7
TOTALS	21	151

The Orbiter lower surface sustained a total of 123 hits, of which 17 had a major dimension of 1-inch or greater. A somewhat unusual finding was eight tile damage sites greater than 1-inch in size on the lower surface left side between the nose gear and LH MLG doors.

The largest tile damage site measured 6.5" x 2.9" x 1.9" (50 percent of the area to substrate) on the LH OMS pod leading edge tile V070-396450-007 and was most likely the result of an ice impact during reentry. Ice may have formed on the waste water dump nozzle due to an on-orbit problem with this system. On-orbit photos taken seven days into the mission confirmed the damage was not present at that time.

Cluster of hits aft of the LH2 and LO2 ET/ORB umbilicals are believed to be impacts from umbilical ice.

LH wing leading edge RCC panel #5 sustained a micrometeorite hit in the upper center area. The impact site measured 0.078 inches in diameter with a depth of 0.025 inches. Post landing inspections in the OPF showed no penetration of the reinforced carbon-carbon material.

No TPS damage was attributed to material from the wheels, tires, or brakes. The tires were in excellent condition after a landing on the KSC runway.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned properly and the debris plungers were seated. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No significant amounts of foam or red purge seal adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve. No debris was found on the runway beneath the ET/ORB umbilical cavities.

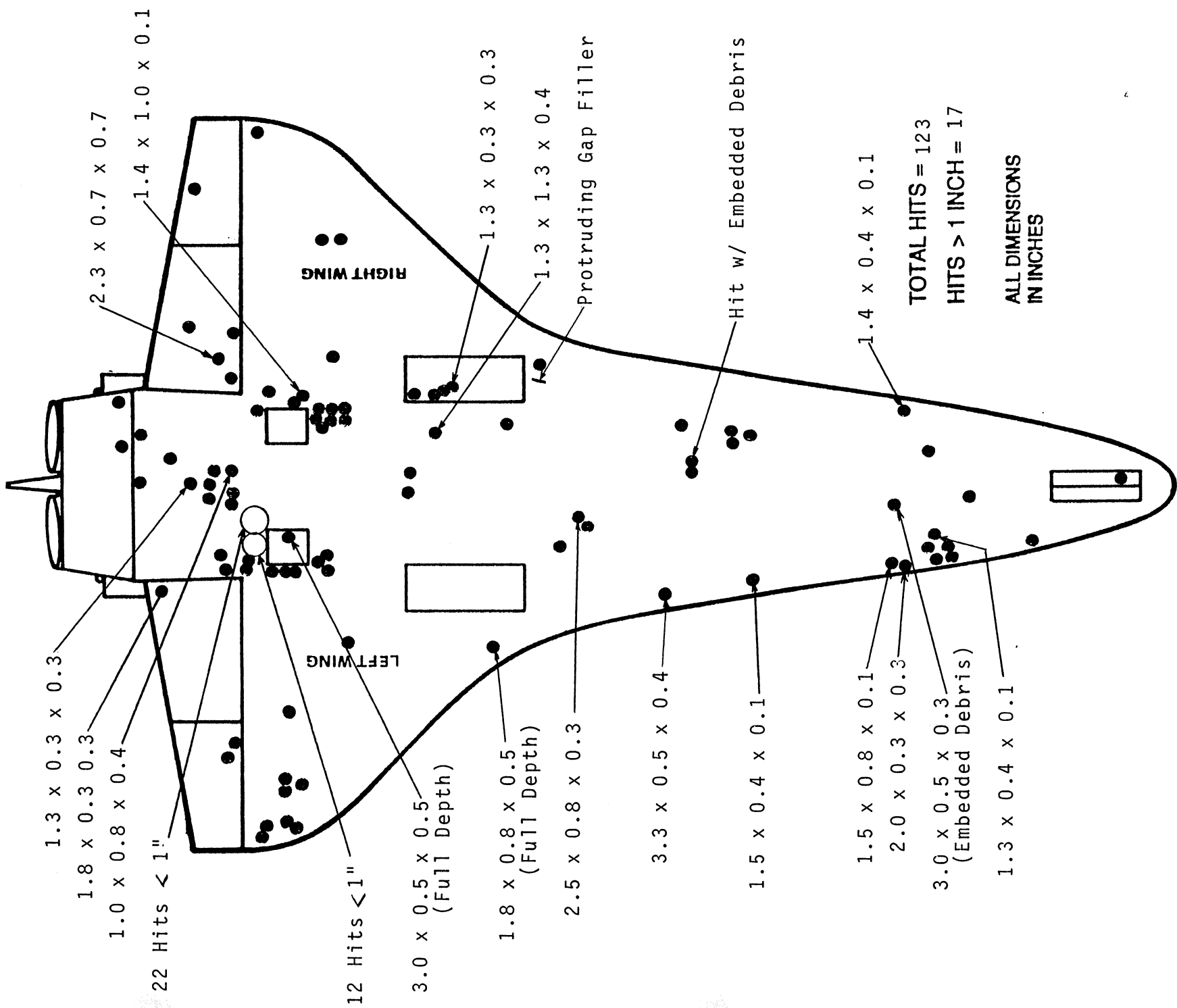


Figure 5 : Orbiter Lower Surface Debris Map

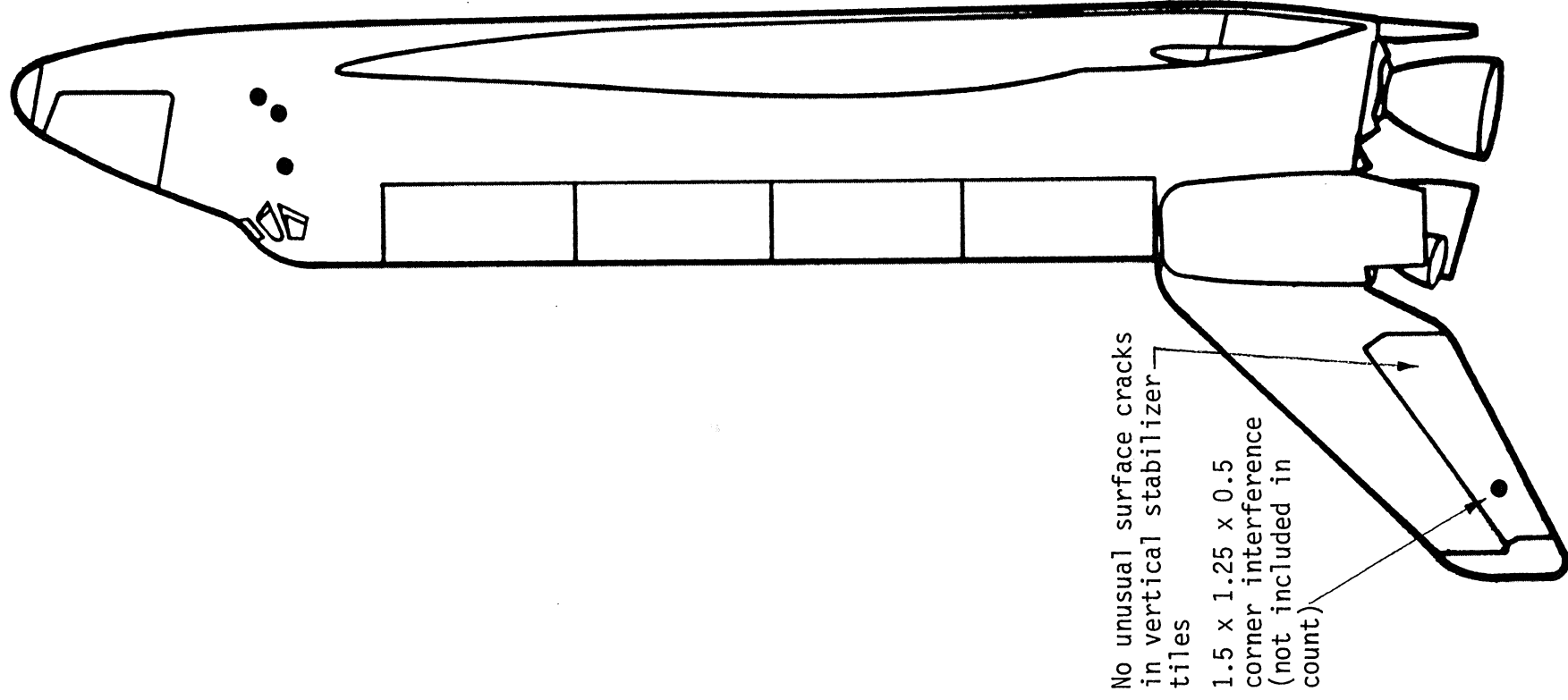


Figure 6 : Orbiter Right Side Debris Map

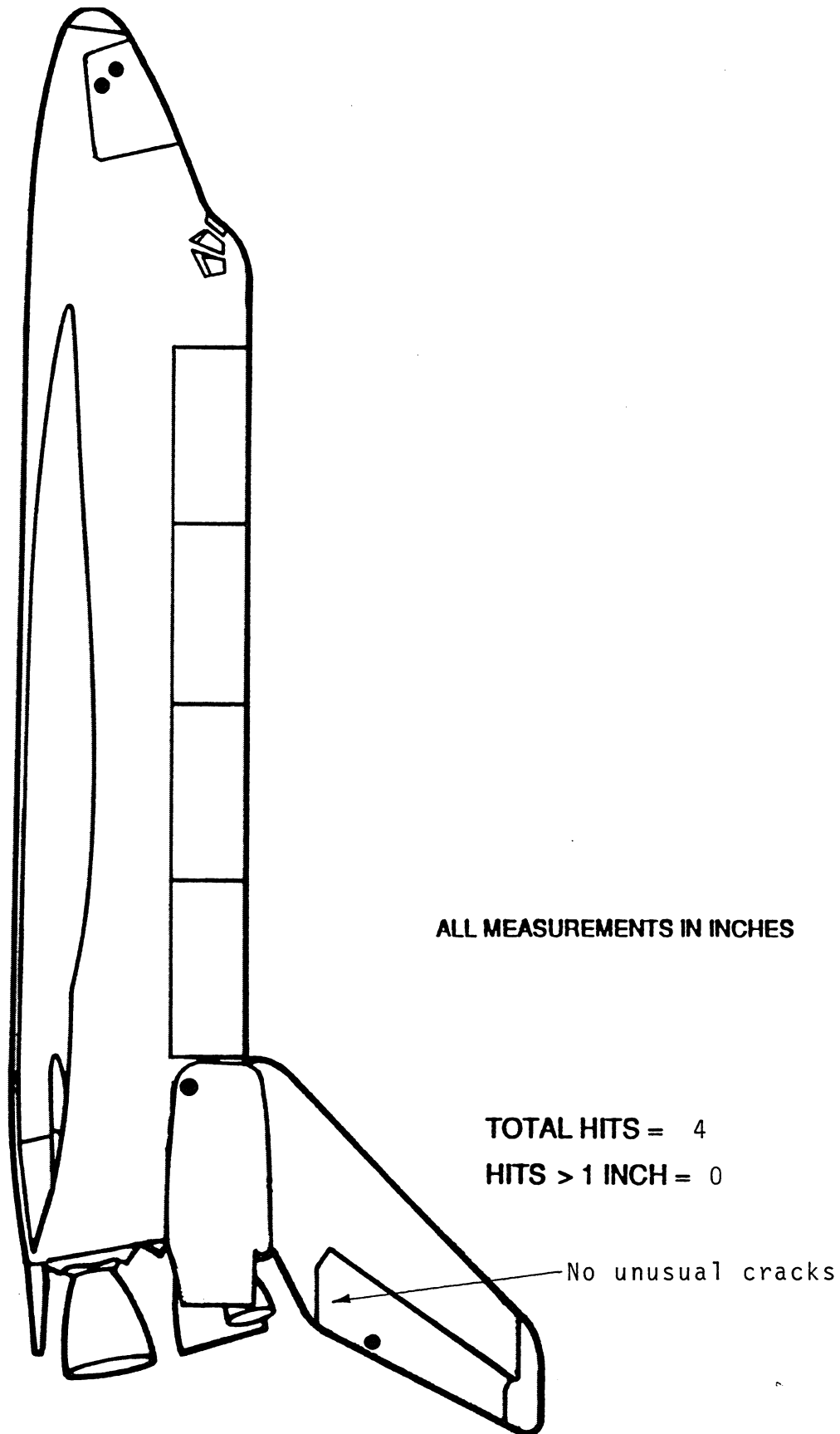


Figure 7 : Orbiter Left Side Debris Map

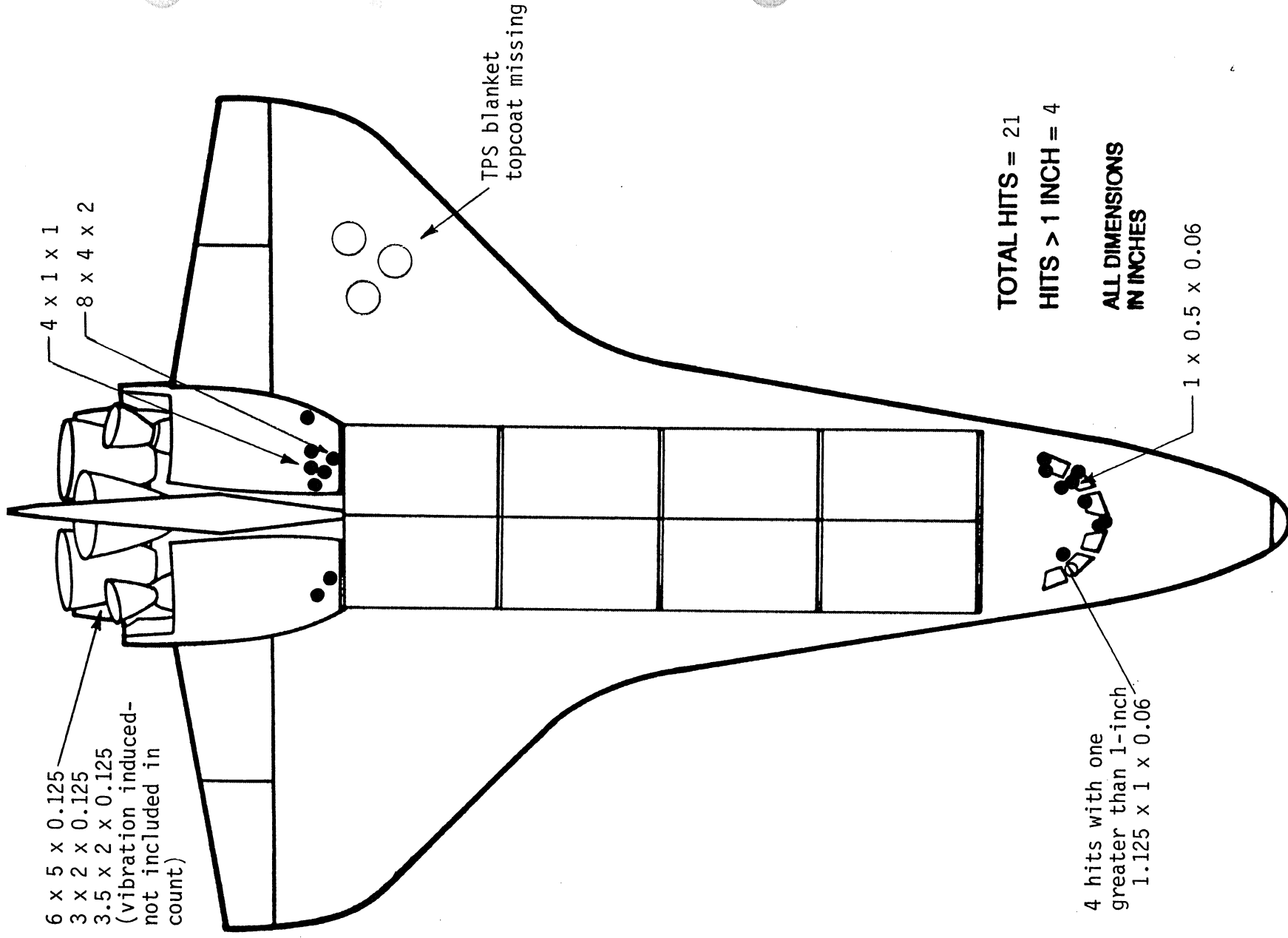


Figure 8 : Orbiter Upper Surface Debris Map

Orbiter windows #3 and #4 exhibited streaks and moderate-to-heavy hazing. Windows #2 and #5 exhibited light-to-moderate hazing. Only a very light haze was present on the other windows. Surface wipes will be taken from all windows for laboratory analysis. Damage on the window perimeter tiles was less than usual. Two lower surface tiles near the Orbiter centerline with orange colored embedded debris particles were identified for chemical analysis sampling.

Tile damage on the base heat shield was typical. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged. Surface coating material was lost from three tiles near the right edge of the body flap upper surface due to SSME acoustics and vibration during flight. These areas measured 6" x 5" x 0.125", 3" x 2" x 0.125", and 3.5" x 2" x 0.125". The Dome Mounted Heat Shield (DMHS) closeout blankets were frayed/ripped on SSME #1 at the 5 to 7 o'clock position. DMHS blankets were loose/unstitched on SSME #2 at the 3 o'clock position and SSME #3 at the 2 o'clock position.

There were no unusual surface cracks on vertical stabilizer tiles.

Runway 33 had been swept/inspected by SLF operations personnel prior to landing and all potentially damaging debris was removed.

The post landing walkdown of Runway 33 was performed immediately after landing. Flight hardware found on the runway included a 6" x 3.25" x 0.06" piece of blanket topcoat from the LH wing upper surface (2910 foot marker near the Orbiter touchdown point), a 3.75" x 2" piece of red cloth material from the drag chute (6425 foot marker), and a 7.25" x 0.875" piece of Ames gap filler near the wheel stop position (13,300 foot marker). All Orbiter drag chute hardware was recovered. No organic (bird) debris was found on the runway. However, a flattened 12-inch fish at the 9500 foot marker appeared to be in line with the LH main landing gear tire rollout track and may have been rolled over by one of the tires. No fish remains were found on the landing gear. The fish was most likely dropped on the runway by a passing bird after the last runway debris sweep and shortly before Orbiter touchdown.

OMRSD V09AJ0.095, which was a requirement to measure the surface temperatures of RCC nose cap and wing leading edge panels with the portable infrared scanner, was recently deleted.

In summary, the total number of Orbiter TPS debris hits was slightly above average and the number of hits 1-inch or larger was average when compared to previous missions (Figures 9-10). The type of TPS damage is typical and not attributable to any single debris source.

Orbiter Post Launch Debris Anomalies are listed in Section 9.0.

Figure 9. **ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY**

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
AVERAGE	13.9	89.5	21.4	130.8
SIGMA	7.3	44.3	10.3	57.6
STS-65	17	123	21	151

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS
SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCE



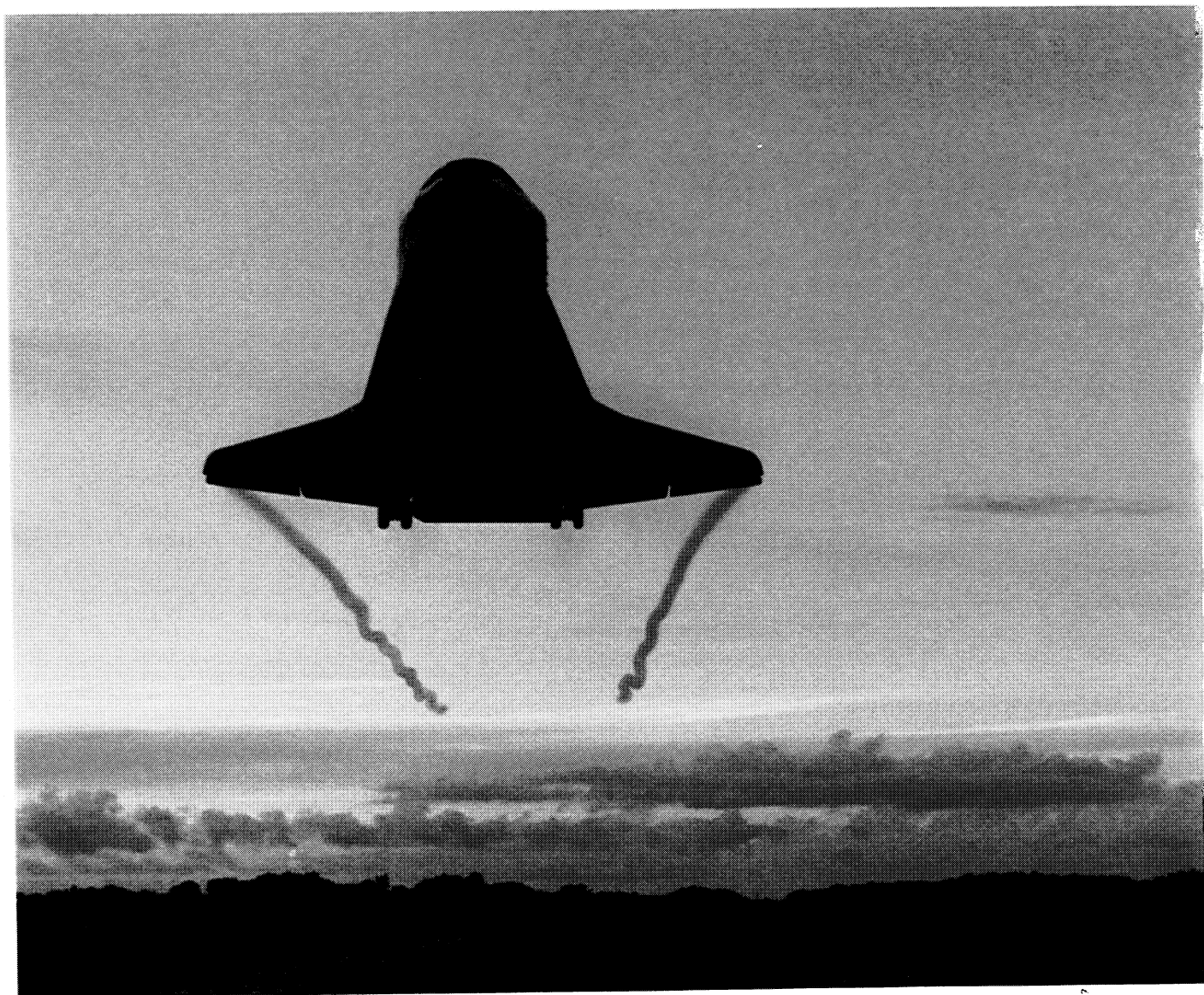


Photo 27 : OV-102 Landing at SLF.



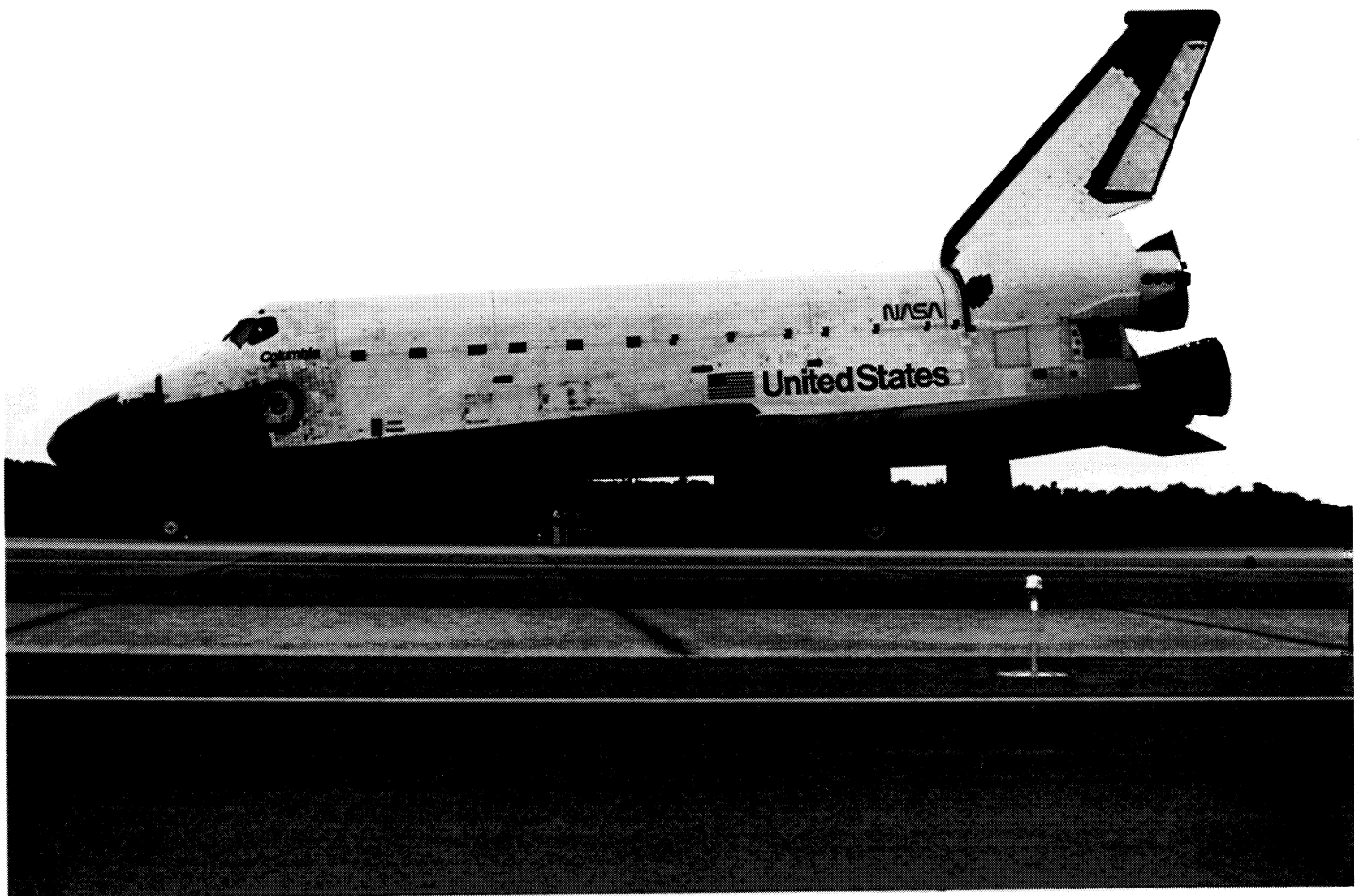


Photo 28 : Overall view of Orbiter left side.



Photo 29 : Overall view of Orbiter right side.



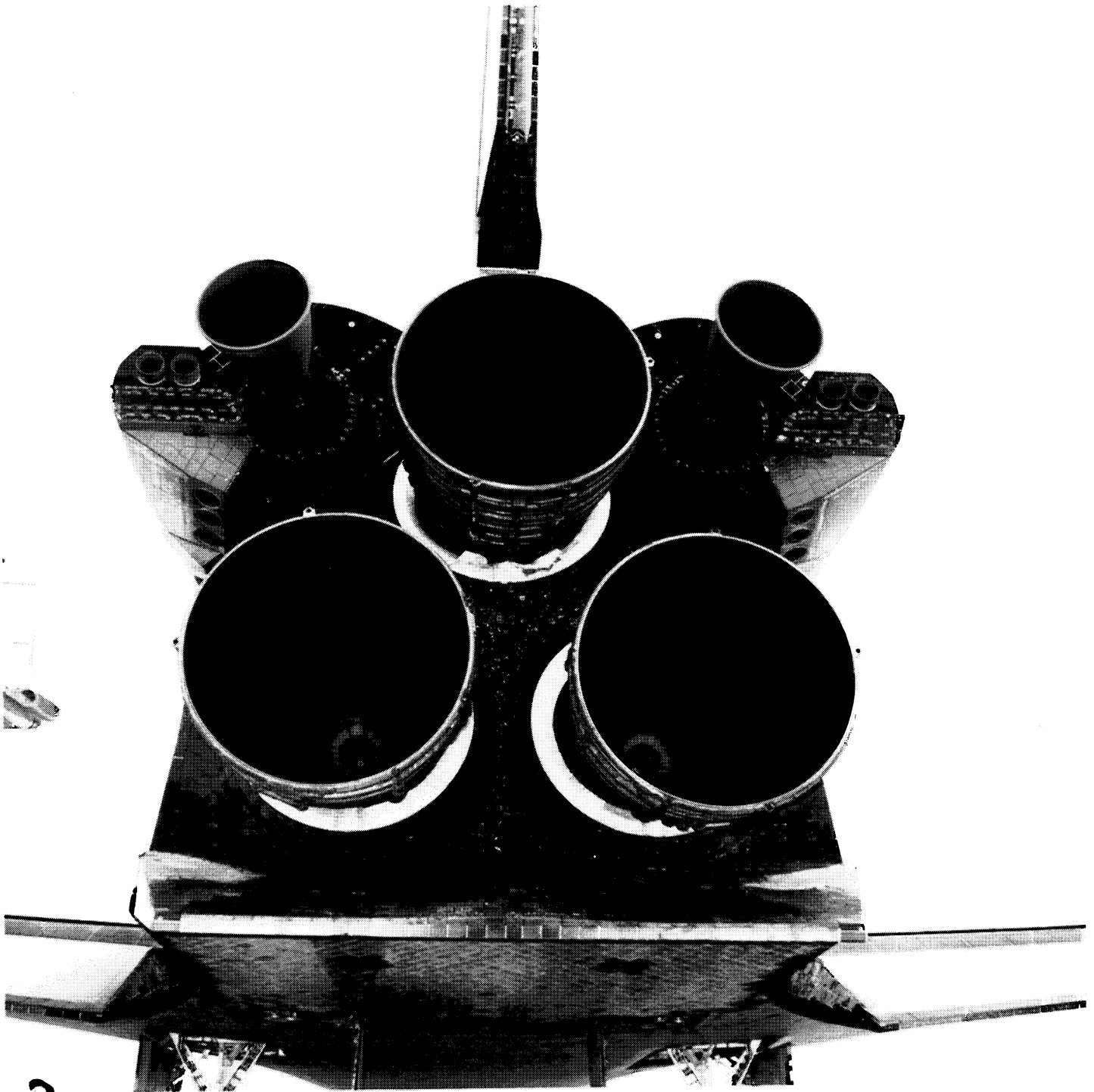


Photo 30 : Overall view of SSME and Base Heat Shield

Note damage to tiles on upper right surface of body flap and torn Dome Mounted Heat Shield closeout blankets at SSME #1 6:00 o'clock position





Photo 31 : Overall view of Orbiter nose and windows.

Orbiter windows #3 and #4 exhibited streaks and moderate-to-heavy hazing. Windows #2 and #5 exhibited light-to-moderate hazing. Only a very light haze was present on the other windows. Damage on the window perimeter tiles was less than usual.



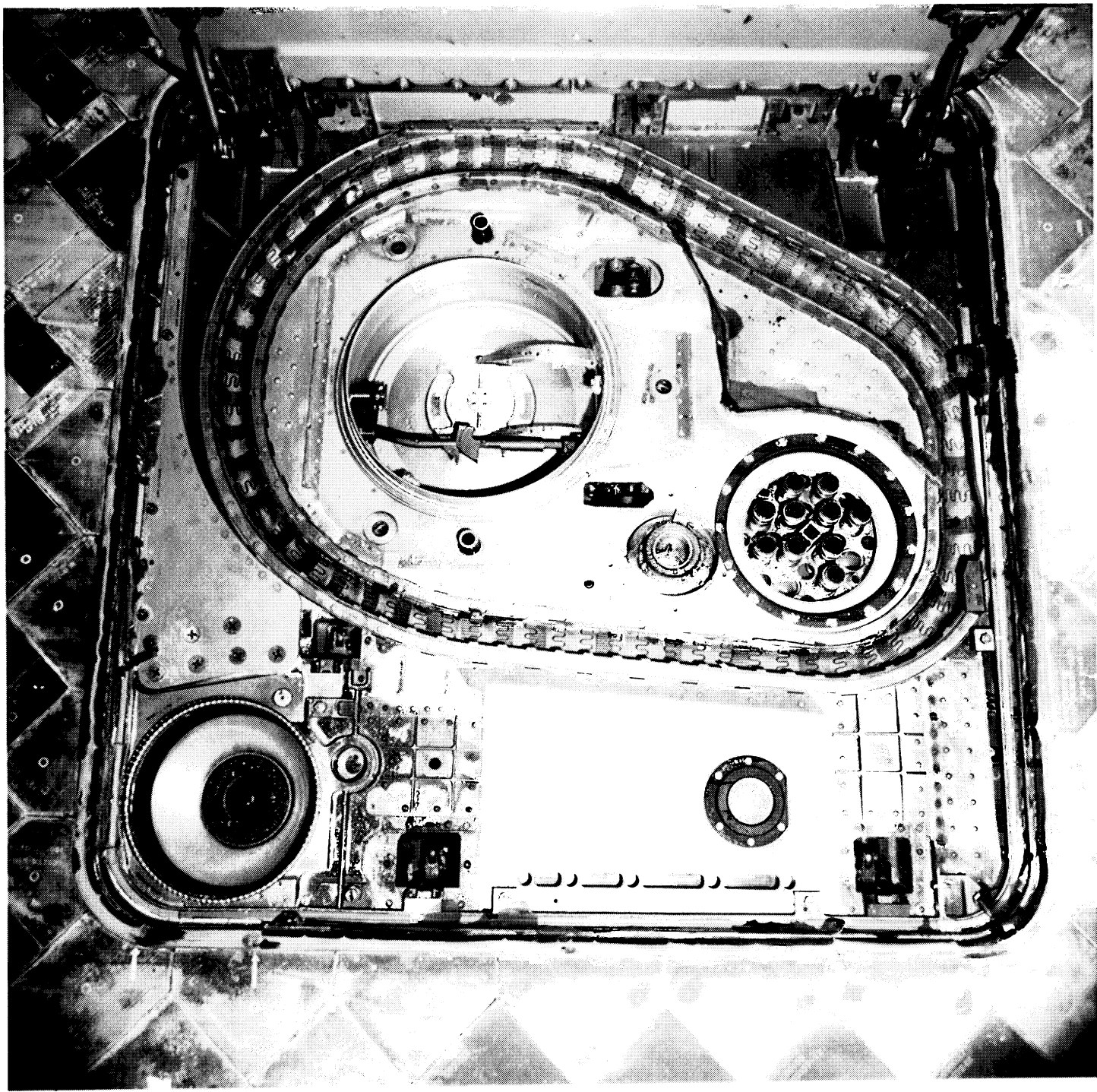


Photo 32 : LO2 ET/Orbiter Umbilical.



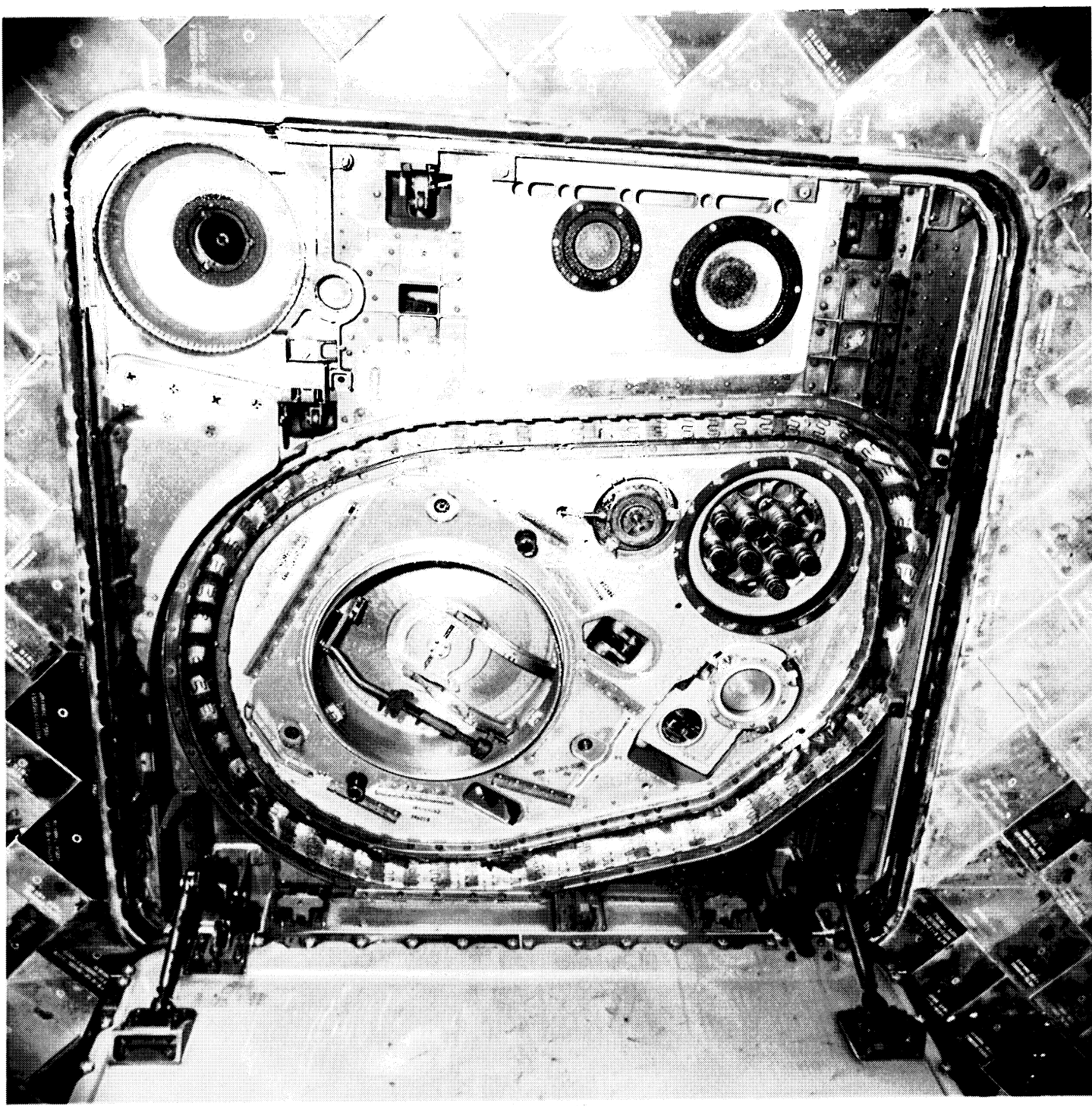


Photo 33 : LH2 ET/Orbiter Umbilical.





Photo 34 : Left OMS Pod tile damage.

The largest tile damage site measured 6.5" x 2.9" x 1.9" (50 percent of the area to substrate) on the LH OMS pod leading edge tile V070-396450-007 and was most likely the result of an ice impact during reentry. Ice may have formed on the waste water dump nozzle due to an on-orbit problem with this system. On-orbit photos taken seven days into the mission confirmed the damage was not present at that time.





Photo 35 : Blanket topcoat missing from LH wing upper surface

The post landing walkdown of Runway 33 was performed immediately after landing. A 6" x 3.25" x 0.06" piece of blanket topcoat from the LH wing upper surface was found at the 2910 foot marker near the Orbiter touchdown point.



8.0 DEBRIS SAMPLE LAB REPORTS

A total of ten samples were obtained from OV-102 Columbia during the STS-65 post landing debris assessment at the Kennedy Space Center. The submitted samples consisted of eight wipes from Orbiter windows 1-8 and two Orbiter tile lower surface damage site samples containing debris inclusions. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

8.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile, tile repair, RTV and glass insulation), paints and primer from various sources. An interesting finding was the variety of paint particulate colors: black, white, red, blue, green, and yellow. No specific source has been determined for the paint particulate. There was no apparent vehicle damage related to these residuals.

8.2 ORBITER LOWER SURFACE TILE

The two samples from the Orbiter lower surface tiles revealed the presence of Orbiter tile material and SRB hypalon paint. Although the paint contained in the damage site samples was fused in appearance, the fact that the paint was not fused within the silicon-rich fibrous tile material does not establish SRB material as the cause for this damage (tile damage sites historically have not retained the damage-causing debris). However, the presence of the paint does confirm that paint is lost/ablated during the first two minutes of flight.

8.3 STS-65 ORGANIC ANALYSIS

The results of the STS-65 organic analysis are included in this report (reference Figure 11). Identified materials include those associated with window covers (plastic polymers), RTV from FRCS thruster nozzle cover adhesive, sealant material typically used on the SRB forward assembly door, and paint from various sources.

8.4 NEW FINDINGS

This set of post-flight debris residual samples provided no new findings. No debris sample trends were apparent when compared to previous mission data (Figure 11).

Figure 11 : Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
65	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
59	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				
62	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				
60	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - Building insulation, textile Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				
61	Metallics - BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - Building insulation, textile Earth minerals - (Landing site) Blue paint particles Organics - Plastic polymers, rubber RTV-RCS nozzle thruster cover Paint and primer				
51	Metallics - BSM Residue (SRB) - Solder (Launch Site) RTV, Tile, Tile coating (ORB TPS) Insulation Glass (ORB TPS) Glass fiber 'E-glass' Organics-Plastic polymer, filled plastic(PVC) Paint		Silica tile material Black and white paints Organics - Plastic polymer, RTV, paint		Left OMS pod- -tile, RTV, silicon carbide

9.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 8 post launch anomalies were observed on the STS-65 mission.

9.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. Debris (pen cap, washer/retainer from the Orbiter 50-1 door closeout) were found on top of the LH2 TSM during the T-3 hour Ice Inspection.

2. The new ECLSS building constructed adjacent to the north side of the FSS sustained severe roof damage from the launch. Pieces of sheet metal lay on the pad near the building, below the RSS, in the field west of the pad near the box cars and against the facility cooling tower.

9.2 EXTERNAL TANK

1. During SRB separation, a cluster of at least 5 pieces of TPS appeared to originate behind the LH2 ET/ORB umbilical cable tray or clam shell closeout. The pieces moved forward and contacted adjacent umbilical TPS surfaces. A piece of foam, approximately 12 inches by 8 inches by 1 inch thick, appeared to originate from the aft surface of the LH2 ET/ORB umbilical cable tray. Loss of foam this thick may have exposed substrate.

2. Two divots, 6 to 8 inches in diameter, were present in the LH2 tank-to-intertank flange closeout immediately to the +Y side of the PAL ramp. Both divots went to substrate and exposed the primer.

3. A divot, 6 inches in diameter but shallow in depth, occurred in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout between the right bipod spindle housing closeout and the LO2 feedline support bracket (XT-1129).

9.3 SOLID ROCKET BOOSTERS

1. Two areas of missing TPS, 2" x 1" and 1" x 1" respectively, were located between the RH frustum -Y and -Z axes and the 275 and 318 ring frames.

9.4 ORBITER

1. The drag chute door got caught in the Orbiter vortices and contacted the pilot chute yoke. There was no damage to the pilot chute and function of both pilot/main drag chutes was not affected.

2. A tile damage site measuring 6.5 inches by 2.9 inches by 1.9 inches deep (50 percent of the area to substrate) was present on the LH OMS pod leading edge tile V070-396450-007 and was most likely the result of an ice impact during reentry. Ice may have formed on the waste water dump nozzle due to an on-orbit problem with that system



Appendix A. JSC Photographic Analysis Summary



Space Shuttle

Photographic and Television Analysis Project

STS-65 Summary of Significant Events

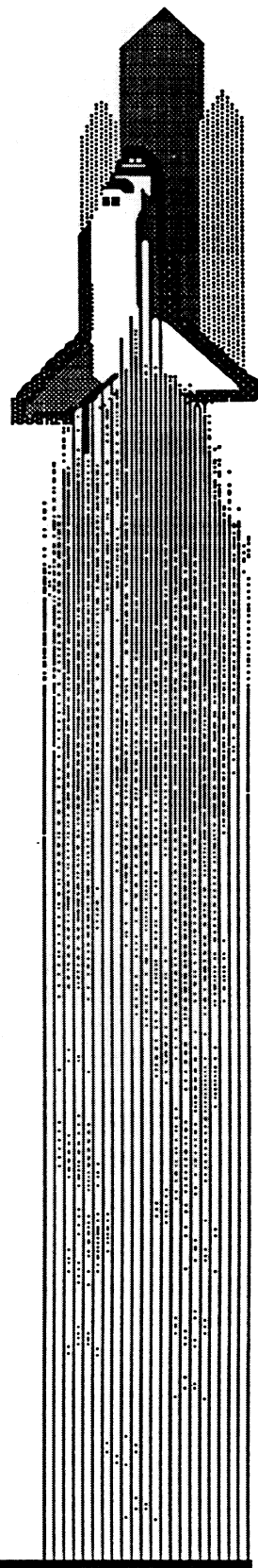
August 26, 1994



NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058



Space Shuttle Photographic and Television Analysis Project

STS-65 Summary of Significant Events

Project Work Order - SN-AFV

Approved By

Lockheed

Christine L. Dailey 8/26/94

C. L. Dailey, Project Specialist
Photo/TV Analysis Project

Robert W. Payne

R. W. Payne, Supervisor
Flight Sciences Support Section

Jess G. Carnes

Jess G. Carnes, Manager
Solar System Exploration Department

NASA

Michael D. Gaunce

Mike Gaunce, Lead
Photo/TV Analysis Project
Flight Science Branch

Prepared By

Lockheed Engineering and Sciences Company
for

Flight Science Branch
Solar System Exploration Division
Space and Life Sciences Directorate



NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

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1.0 OV-102 STS-65 Film/Video Screening and Timing Summary

1.1 SCREENING ACTIVITIES

1.1.1 Launch

Columbia (OV-102) launched on mission STS-65 from Pad A at 16:43:00.023 Coordinated Universal Time (UTC) on July 8, 1994 (day 189) as seen on camera E-9. Solid rocket booster (SRB) separation occurred at 16:45:03.507 UTC as seen on camera E-212.

On launch day, 24 videos were screened. Following launch day, 53 films were reviewed. E-76 film was not received due to camera problems.

No anomalies were observed during launch.

Detailed Test Objective (DTO)-312 photography of the STS-65 external tank (after separation) was acquired with a Nikon camera with a 300 mm lens and a 2X extender (method 3). Thirty eight exposures from magazine 01 were received. The aft dome, the +z, -y, -z sides and the nose cone of the ET were imaged. Video of the STS-65 external tank (after separation) was downlinked by the astronauts. Two 16 mm motion picture cameras (with 5 mm and 10 mm lenses respectively) captured LSRB separation and the left side of the external tank during ET separation. A 35 mm still frame Nikon camera captured the right side of the ET (method 1). See section 2.4.1, Analysis of Handheld Photography of the ET (Task #6) and section 2.4.2, Umbilical Well Camera Analysis (Task #5) for details.

1.1.2 On-Orbit

No significant on-orbit events were analyzed on this mission.

1.1.3 Landing

The first attempt for landing of STS-65 on July 22, 1994 at the Kennedy Space Center (KSC) was waived due to weather constraints.

Columbia landed on runway 33 at KSC on July 23, 1994 (day 204). Twelve videos of the Orbiter's approach and landing were received. NASA Select, a composite of multiple real-time views, was also received. Left main gear touchdown was at 10:37:59.448 UTC, right main gear touchdown occurred at 10:37:59.549 UTC, and nose wheel touchdown was at 10:38:17.266 UTC as seen on camera KTV-33L. Wheel stop was noted at 10:39:07.316 UTC on camera KTV-15L. No major anomalies were noted in any of the approach, landing and rollout video views screened.

Fourteen landing films were received from KSC and screened.

The drag chute door may have contacted the pilot chute after release. Details of the analysis performed on this event can be found in section 2.6.2, Drag Chute Performance (Task #9).

The following items were noted during the post-landing walk around: damage to the Thermal Protection System (TPS) on the left Orbital Maneuvering System (OMS) pod, surface damage to the area around the potable and waste water dump ports and damage to the thermal blankets on the space shuttle main engine (SSME) dome mounted heat shield (DMHS). (See Figure 1.1.3.) Other items noted include: reddish fluid on the leading edge of the right nose gear door, the condition of the right main gear outboard brake, and the

condition of the liquid hydrogen (LH2) and liquid oxygen (LO2) umbilical wells. The drag chute housing and the tires appeared to be in satisfactory condition. Minor tile damage was noted on the Orbiter and the base heat shield tile damage was typical.

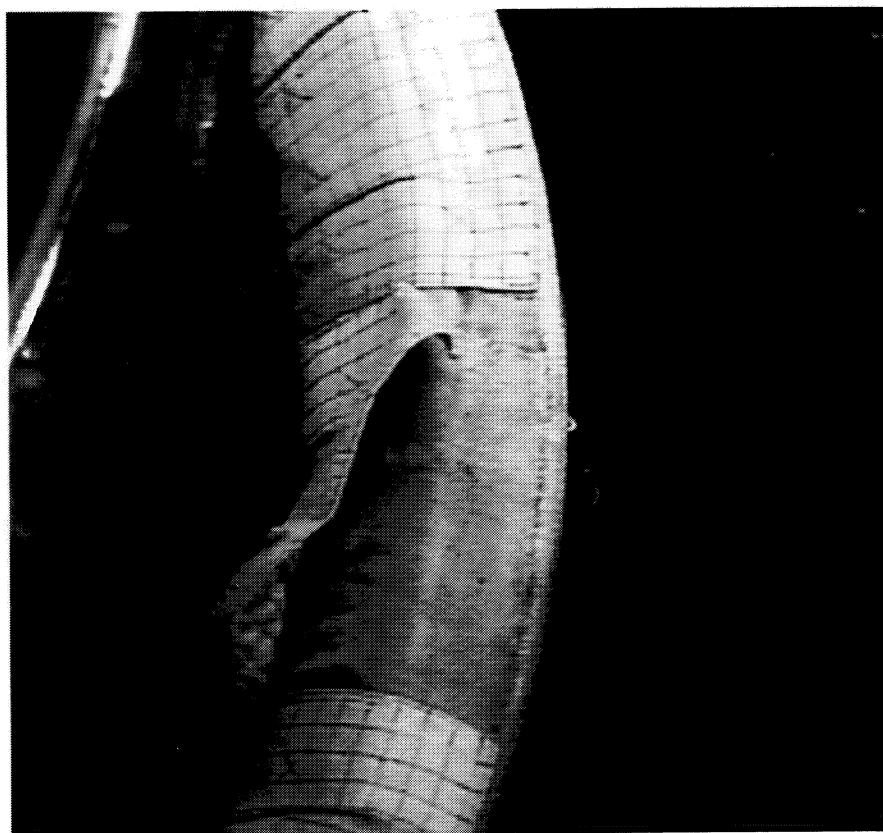


Figure 1.1.3 **Damage to the SSME #2 DMHS**

Damage was seen to the SSME DMHS closeout blankets. This type of damage has been seen on earlier missions. No further analysis was requested.

1.2 TIMING ACTIVITIES

All launch videos had timing. Launch film cameras E-1, E-2, E-3, E-4, E-5, E-6, E-7, E-8, E-9, E-10, E-11, E-13, E-14, E-15, E-16, E-17, E-18, E-19, E-25, E-26, E-52, E-54, E-57, E-59, E-222 and E-224 had in-frame alphanumeric timing. Landing videos KTV5L, KTV6L, KTV11L, KTV12L, KTV13L, KTV15L, KTV20L, KTV33L had timing. Of the landing films, EL-1, EL-2, EL-4, EL-5, EL-7, EL-8, EL-9, EL-10, EL-12, EL-19 and EL-20 had in-frame alphanumeric timing. All of the videos and films were used to time specific mission events during the initial screening. SRB separation was timed on two film cameras:

E-204: SRB Separation	189:16:45:03.509
E-212: SRB Separation	189:16:45:03.507

ORIGINAL PAGE
COLOR PHOTOGRAPH



2.0 Summary of Significant Events

2.1 DEBRIS

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 Tail Service Mast (TSM) T-0 Umbilical Disconnect Debris (Cameras E-2, E-17, E-18, E-19, E-77 and OTV-070)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at SSME ignition through liftoff. None of the debris was observed to strike the vehicle. No follow-up action has been requested.

2.1.1.2 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris (Cameras E-5, E-6, E-16, E-18, E-19, E-31, E-34, E-35, E-40, E-52, E-60, E-63, E-65, E-77, OTV-009, OTV-051, OTV-054, OTV-061 and OTV-063)

Normal ice debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. At least 6 instances where ice struck the LH2 umbilical door sill were seen after SSME startup on camera OTV-009. No damage was visible in that area. No follow-up action was requested.

2.1.2 Debris During the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris (Cameras E-1, E-7, E-8, E-9, E-11, E-12, E-13, E-14, E-15 and E-16)

As on previous missions, several pieces of debris were noted originating from the SRB flame duct area after SRB ignition. None of the debris warranted velocity measurement. No follow-up action was requested.

2.1.2.2 Debris from Body Flap Hinge Area at Liftoff (Camera E-17)

A single piece of small light colored debris originated from the starboard corner of the body flap hinge area and fell aft along the body flap at liftoff. The debris may have been a piece of ice that became dislodged at SRB ignition. No follow-up action was requested.

2.1.3 Debris after Liftoff

Multiple pieces of debris were seen falling aft of the shuttle launch vehicle (SLV) at liftoff, throughout the roll maneuver, and beyond on the launch tracking views. Most of the debris sightings were probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. None of the debris was observed to strike the vehicle. No follow-up action was requested. The crew did not report on debris seen during ascent.



2.0 Summary of Significant Events

2.2 MLP EVENTS

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen) (Cameras E-2, E-3, E-5, E-18, E-19, E-30, E-52, E-62, E-77, OTV-063 and OTV-071)

Orange vapor (possibly free burning hydrogen) was seen beneath the body flap just prior to SSME ignition. The vapor was also noted near the SSME bells on camera E-5 and E-19 prior to SSME ignition. This event has been noted on past missions and would become a concern if the vapor was seen near the umbilical areas. On this mission, however, the vapor was well below the umbilicals and no follow up action was requested.

2.2.2 Flashes in SSME Plumes after SSME Ignition (Cameras E-2, E-3 and E-19)

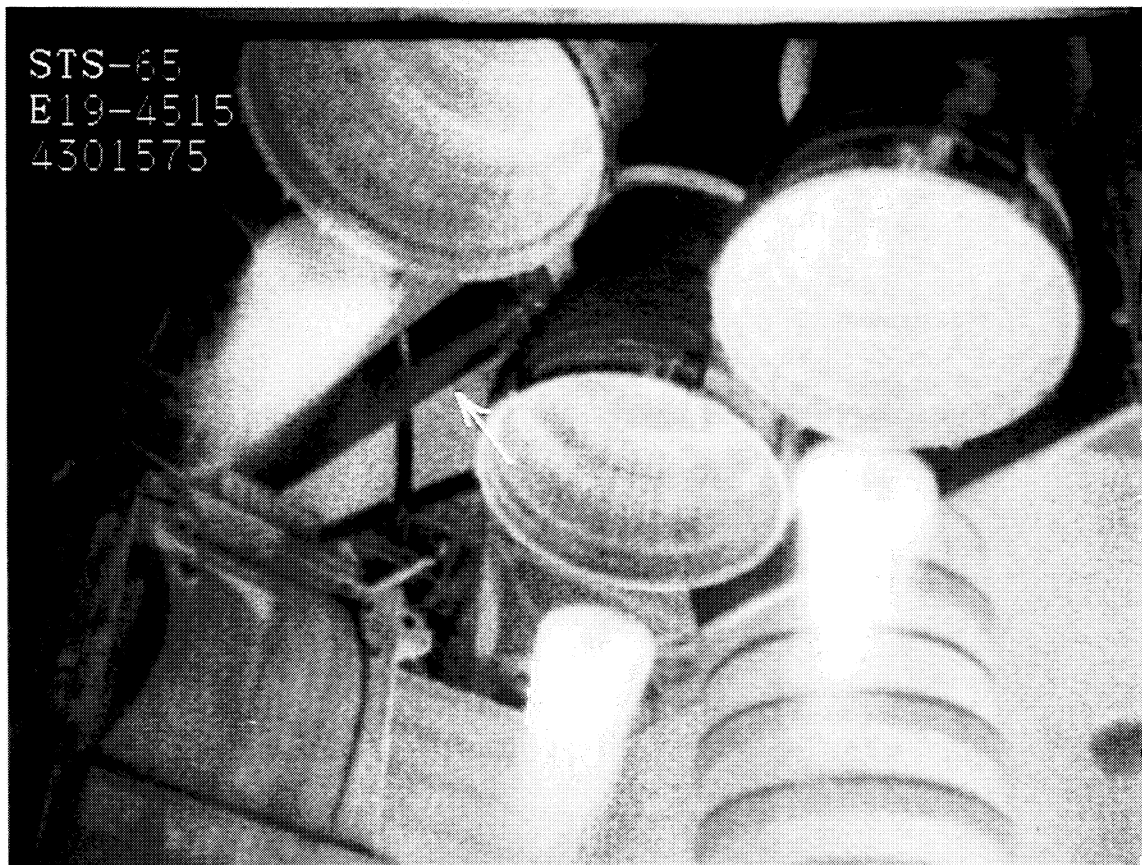


Figure 2.2.2 Flash in the SSME #1 plume
(Camera E-19)

A single orange flash was noted in the SSME #1 plume at T-2.2 seconds. (See Figure 2.2.2). A flash was also seen in the SSME #3 plume at 0.9 seconds MET. Both of these flashes may have been due to debris entering the plume. This event has been seen on earlier missions. No follow-up analysis has been requested.



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2.0 Summary of Significant Events

2.2.3 Loose Thermal Curtain Tape on RSRB (Camera E-10, E-15)

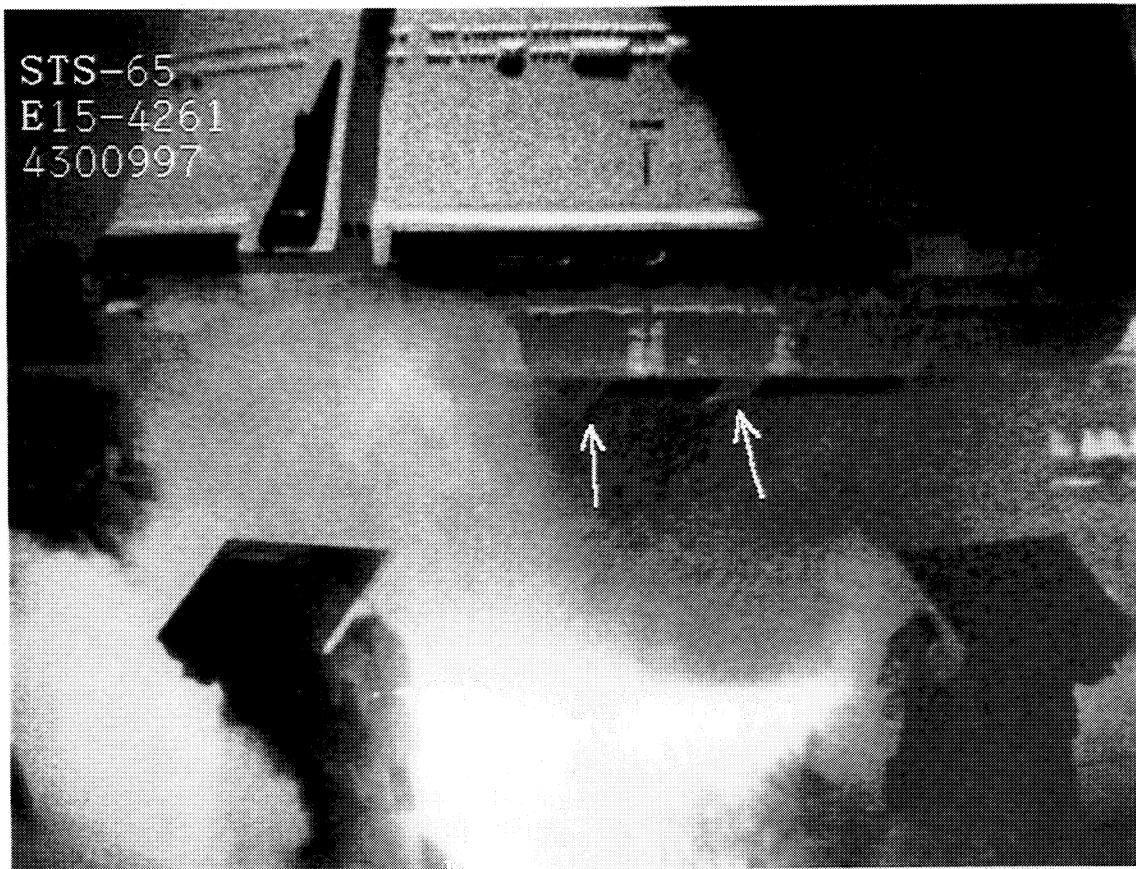


Figure 2.2.3 Two Loose Pieces of Thermal Curtain Tape on RSRB
(Camera E-15)

Two pieces of loose thermal curtain tape were noted on the RSRB aft skirt just after liftoff. This event has been seen before. No follow-up action was requested.

2.2.4 Base Heat Shield TPS Erosion (Cameras E-17, E18 and E-20)

Slight TPS erosion was noted at the base of both the left and right RCS stingers. More erosion was observed on the base heat shield near the SSME #2 and SSME #3 DMHS. Erosion of the base heat shield TPS has been seen on previous missions. No follow up action was requested.

2.3 ASCENT EVENTS

2.3.1 Body Flap Motion (*Task #4*) (Cameras E-212 and E-220)

During ascent, slight body flap motion was noted between 22 and 50 seconds MET. The magnitude of the motion seen on the STS-65 views was not sufficient to warrant further analysis.

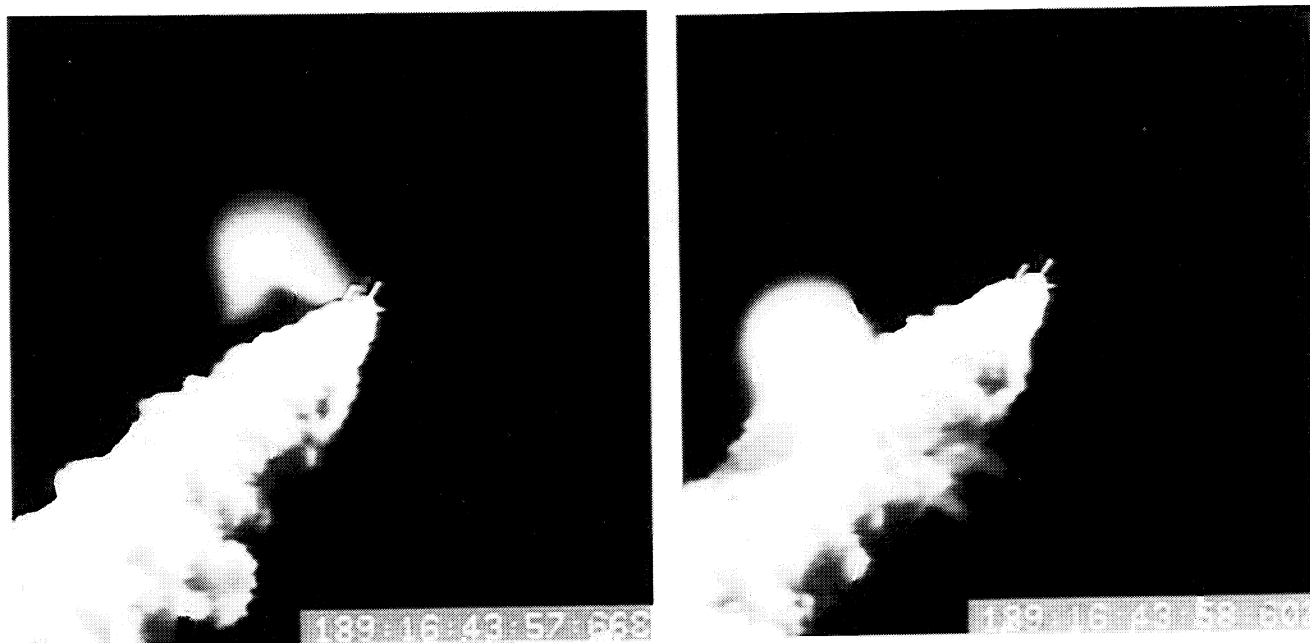


2.0 Summary of Significant Events

2.3.2 Condensation Vapor Cloud at 58 seconds MET (Cameras E-204, E-205, E-207, E-208, E-212, E-213, E-218, E-220, E-222, E-223, ET-204, ET-207, ET-208, ET-212, ET-213, KTV-4A, KTV-13, KTV-15 and KTV-21A)

Condensation was noted around the SLV between approximately 37 and 58 seconds MET. A large cloud was seen near the SRB plume between 57.0 and 58.2 seconds MET. Launch trajectory data indicated that the vehicle would be at an altitude of 34,150 feet at this time. No rawinsonde data (identifying moisture layers) were available for altitudes above 33,000 feet. This event was previously seen at the same MET on both STS-48 and STS-62.

Studies performed by both the JSC Engineering Directorate's Aeroscience Branch and the Rockwell Downey Aerodynamics group indicate that the event was most likely due to SLV interaction with atmospheric moisture and is not considered a flight issue.



(a)

(b)

Figure 2.3.2 White Vapor Cloud Around Vehicle at 58 seconds MET
(Camera KTV-5)

A large white cloud (probably due to Orbiter interaction with the atmosphere) is seen near the vehicle between 57 and 59 seconds MET. This image pair shows the change in the vapor cloud over a one second interval.



2.0 Summary of Significant Events

2.3.3 Linear Optical Effect (Cameras E-212 and E-220)

Linear optical effects were seen between 78 and 90 seconds MET. Engineers at JSC have previously attributed similar events seen on earlier missions to the manifestation of shock waves around the SLV. No follow-up action was requested.

2.3.4 Recirculation (Cameras E-204, E-208, E-212, E-220, ET-204, ET-208, ET-212 and KTV-13)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all previous missions. Recirculation on STS-65 was observed between 93 seconds and 115 seconds MET on the cameras shown in the table below.

Cameras on which recirculation was observed for STS-65

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-204	95	111
ET-208	93	115
**ET-212	---	---
KTV-13	94	111
*E-204	95	112
E-208	93	105
E-212	95	104
**E-218	---	---
**E-220	---	---

* Best view of recirculation

** Exact start and stop times were not available for ET-212, E-218 and E-220

2.4 Onboard Photography of the ET (DTO 312)

2.4.1 Analysis of Handheld Photography of the ET (*Task #6*) (S65-315-01 through 37 and L1 Camcorder Video)

DTO-312 photography of the STS-65 external tank (after separation) was acquired with a Nikon camera with a 300 mm lens and a 2X extender (Method 3). This 35 mm handheld photography was reviewed on Tuesday, July 26, 1994. Thirty-eight exposures from magazine 01 were received. The exposure of the ET is good on 26 frames and the rest are in deep shadow. Focus is variable. Timing data is on the film. The pictures were taken over a 9 minute, 55 second time interval starting 3 minutes, 51 seconds after ET separation.

The ET appeared to be in very good shape. No divots were visible. On Frame 9, a bright area to the left of the RSRB forward attach point appeared to be caused by sun glint. A piece of white debris seen on frames 12, 15, and 16 may be ice traveling with the ET. On Frames 19, 20 and 21, a red spot is detectable in the charred area below the nose cone. (Steve Copsey of Martin Marietta reported that this may be a sanded area.)

Forty-three seconds of video of the STS-65 external tank (after separation) was down linked by the astronauts. No anomalies on the ET surface features or TPS were detected.



2.0 Summary of Significant Events

The exposure of the ET is dark. Motion or jitter of the ET hampered analysis. The aft dome, the +z, -y, -z sides of the ET were imaged. Typical charring on the ET aft dome is visible. No event times were received with the downlinked video.

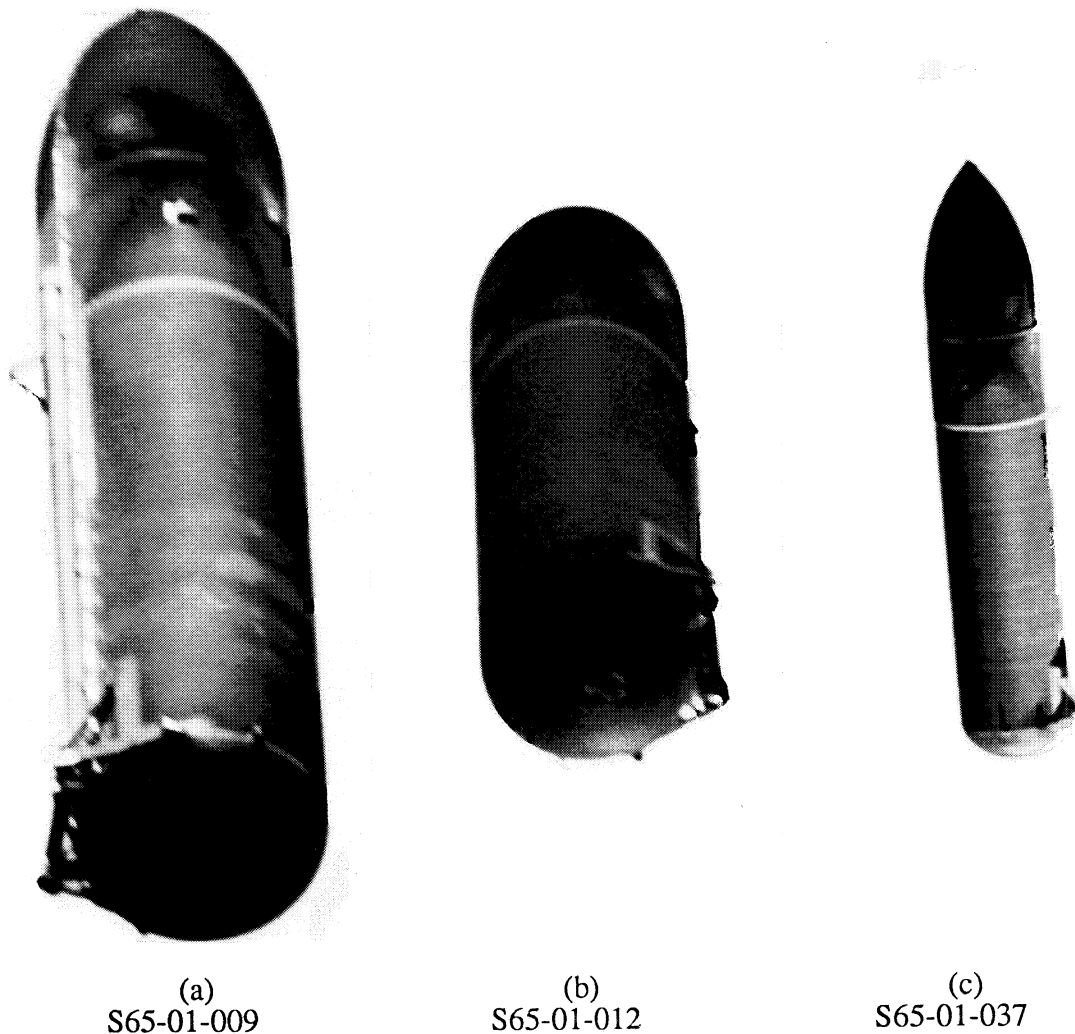


Figure 2.4.1 Three Handheld Views of the External Tank after Separation

These three views of the external tank were taken with a Nikon camera. Figure 2.4.1a shows the right side and aft end, (b) shows the aft end and left side, and (c) shows the left side. The ET appeared to be in good condition. Normal scarring from recirculation and SRB separation was visible.



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2.0 Summary of Significant Events

2.4.2 Umbilical Well Camera Analysis (Task #5)

2.4.2.1 16 mm Umbilical Well Camera Views of LSRB and ET Separation

Two 16 mm motion picture films (one taken with a 5 mm lens and the other with a 10 mm lens) were acquired from the Orbiter LH2 umbilical cameras. The 16 mm film sequence of the SRB separation is of good quality. The LSRB separation and the external tank separation appeared normal. The 16 mm umbilical film sequence of ET separation had variable exposure due to sun glare and the view of the ET after separation is totally obscured by the sun's glare about a third of the way through the film. The focus was soft to good. No timing was available on these films.

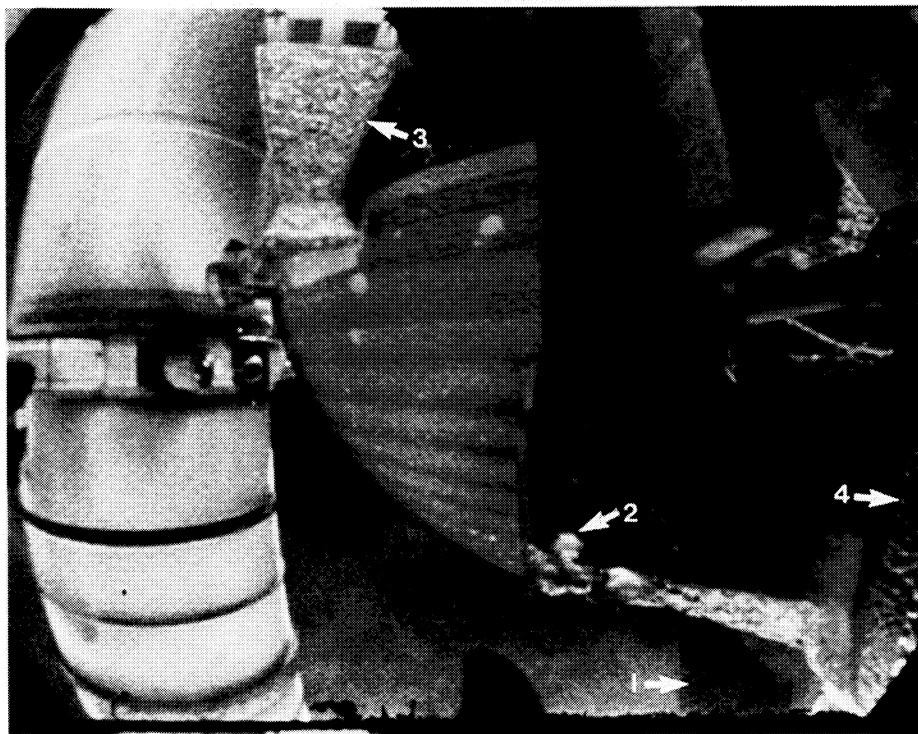


Figure 2.4.2.1a LSRB at Separation
(Frame S65-1013-1113)

A large piece of debris (probably insulation) was seen below the electrical cable tray at SRB separation (1). Typical chipping and erosion of the -Y electrical cable tray was visible (2). Erosion and scarring of the ET/Orbiter aft attach was seen (3). A blistering of the fire barrier coating on the outboard side of the LH2 umbilical was apparent (4). Several small light colored pieces of debris (probably insulation) were visible striking the electric cable tray prior to and after SRB separation. The SRB separation appeared as expected.



2.0 Summary of Significant Events

The ET separation appeared as expected. At the time of depressurization, several pieces of ice were noted as well as what appeared to be small pieces of insulation. Two grey, flat, thin, rectangular-shaped pieces of debris were seen to the left of the electrical cable tray after ET separation. Several small bright pieces of debris were noted near the LSRB attach area throughout the ET separation phase. Several larger pieces of white debris (probably frozen hydrogen) can be seen floating to the left of the umbilical area after separation (E1013-frame 5389). None of this debris appeared to damage the ET structure. Loose, tape-like debris was noted attached to the cross beam (E1013-frame 6282). Following the obscuration of the ET by the sun, multiple pieces of white debris moved through the scene.

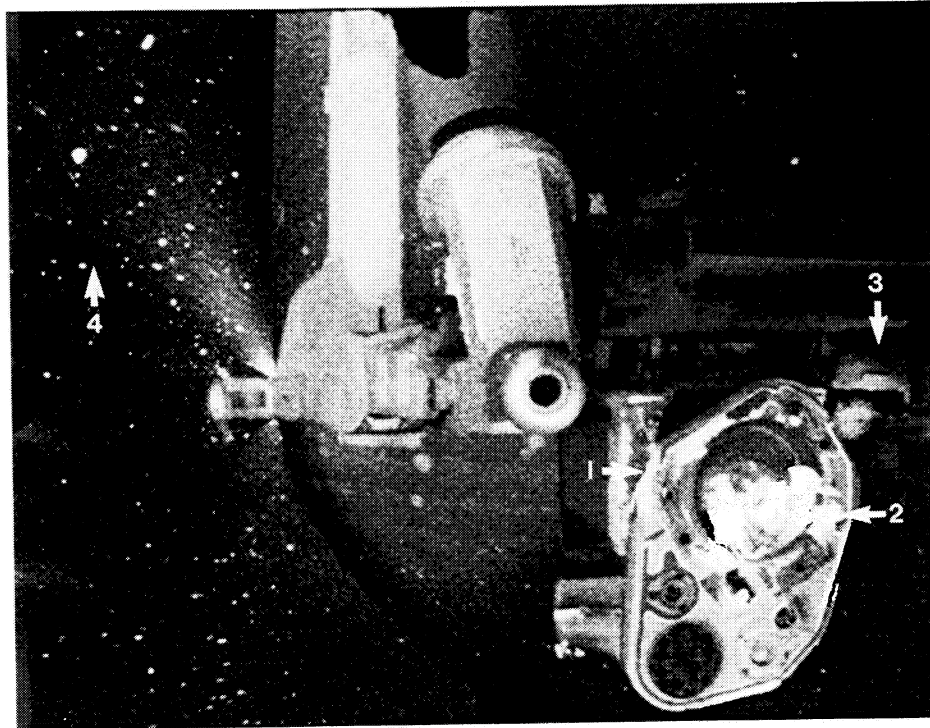


Figure 2.4.2.1b **LH2 Umbilical After ET Separation**
(Frame S65-1003-6100)

Damage to the insulation on the umbilical carrier plate was visible at the ten o'clock position. (1). Frozen hydrogen was visible in the LH2 17 inch line connection as well as in the area surrounding the 17" line (2). A light colored area (possible frozen hydrogen) was seen to the right of the umbilical on the ET (3). Small, bright debris was visible near the SRB aft attach point (4).



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2.0 Summary of Significant Events

2.4.2.2 35 mm Umbilical Well Camera Views of ET Separation

Forty three exposures of the external tank were taken with the 35 mm umbilical well camera. The 35 mm film was underexposed but camera focus was good for most areas on the tank. Timing data was not present nor expected on the 35 mm film.

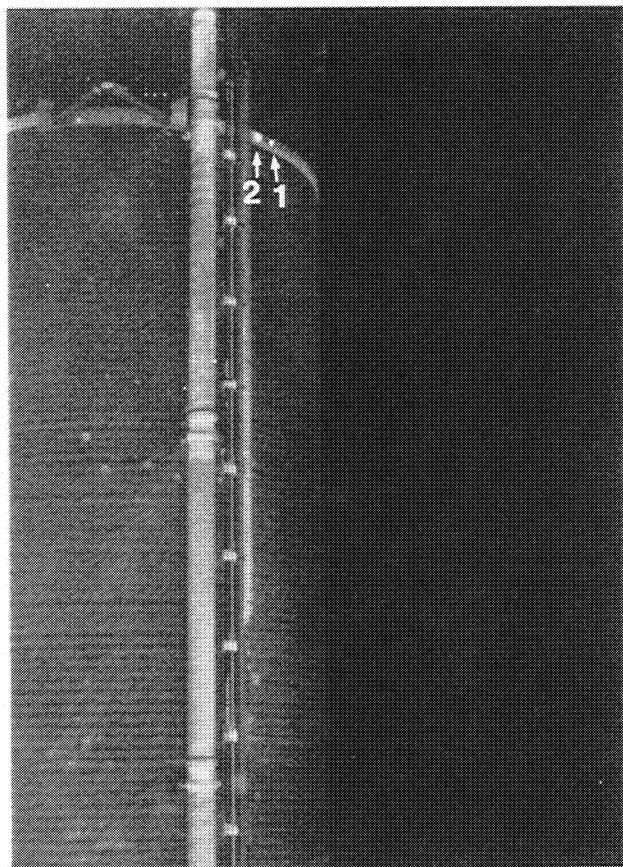


Figure 2.4.2.2a Divots on the LH2 Intertank Interface
(Frame S65-53-41)

Two white marks were visible on the LH2 intertank interface located in the +Y direction from the ET/Orbiter forward attach bipod (1 and 2). The first mark measured approximately 7 by 5 inches, while the second mark was approximately 10 by 7 inches.



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2.0 Summary of Significant Events

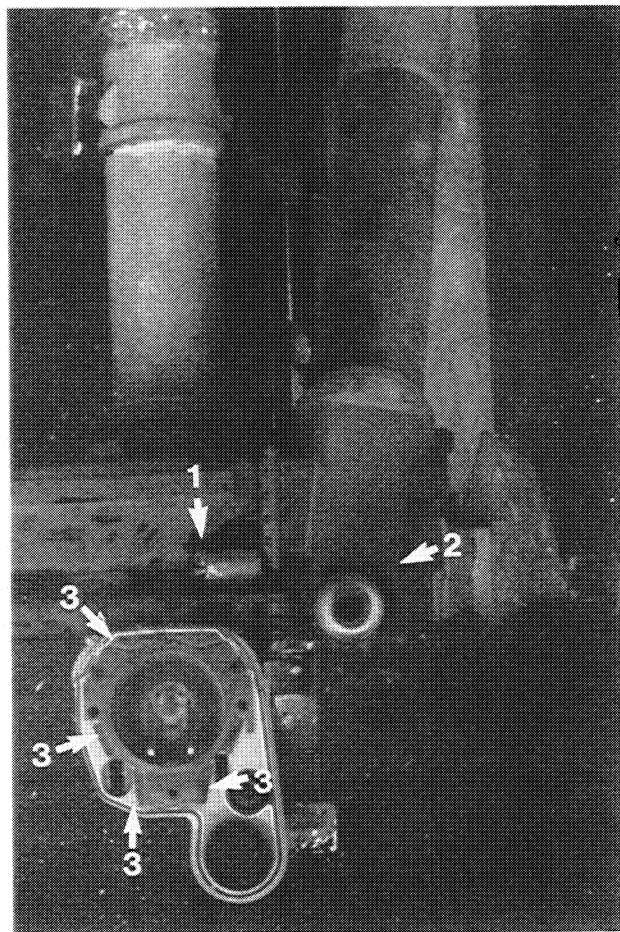


Figure 2.4.2.2b ET LO2 Umbilical and Aft Strut Area
(Frame S65-53-10)

Slight TPS erosion was visible on the aft section of the ET. All speckled areas observed on the 35 mm umbilical well film were verified on the closeout photographs. A divot was noted on the fixture between the diagonal strut and the crossbeam (1). The red seal around the EO-3 fitting appeared to be intact (2). Four of the five LO2 umbilical lightning contact strips did not seem to be present based on the absence of a metallic tone and edge relief typical to the surrounding area (3). JSC engineers were notified of the possible missing lightning contact strips.

2.5 ON ORBIT EVENTS

No on orbit events were analyzed this mission.



2.0 Summary of Significant Events

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis (*Task #3*)

2.6.1.1 Landing Sink Rate Analysis Using Film (Cameras EL-7 and EL-9)

Camera EL-9 was used to determine the landing sink rate of the main gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 100 frames per second. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter y-axis. Scaling information was determined by using the distance between the main gear struts. The vertical difference of the projected main gear point for two successive frames was multiplied by the scaling factor to find the change in height of the main gear over that interval. The main gear height above the runway was determined by assigning the frame of touchdown a height of 0 feet, and cumulatively adding the previous frames. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The main gear sink rate was calculated from the last full second, half second and quarter second interval. These rates were 2.3, 1.9 and 1.4 feet per second respectively.

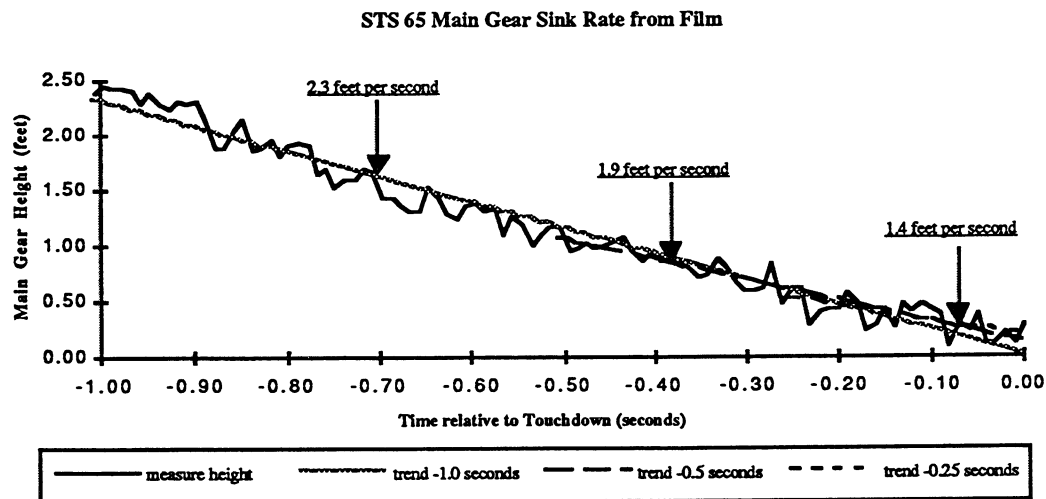


Figure 2.6.1.1a Film Main Gear Sink Rate

2.0 Summary of Significant Events

Camera EL-7 was used to determine the landing sink rate of the nose gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 100 frames per second. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter y-axis. Scaling information was determined by using the distance between the main gear struts. The vertical difference of the digitized nose gear point from the average of the main gear points was multiplied by the scaling factor to find the height of the nose gear for a single frame. An empirical offset correction was made to produce a calculated height at main gear touchdown of 0 feet. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The nose gear sink rate was calculated from the last full second, half second and quarter second interval. These rates were 4.3, 5.4 and 5.9 feet per second respectively.

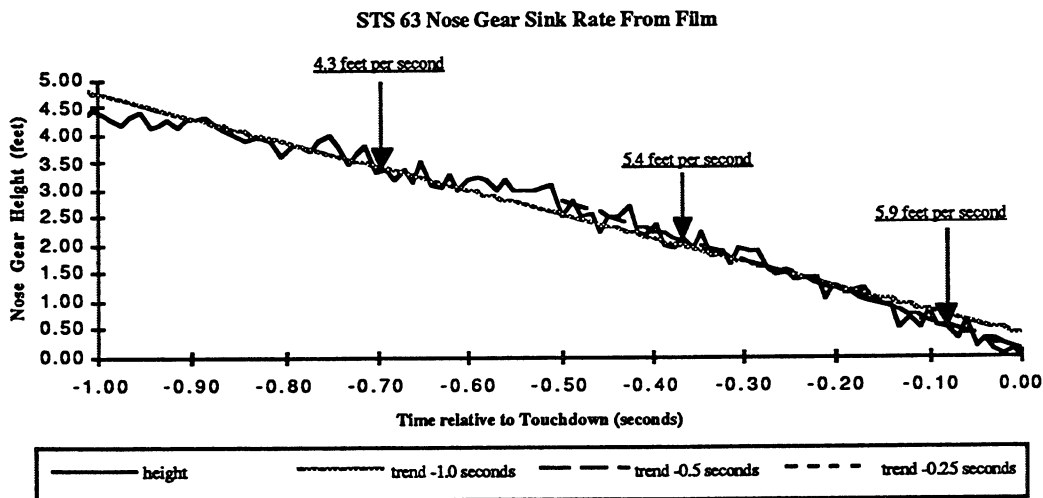


Figure 2.6.1.1b Film Nose Gear Sink Rate

2.0 Summary of Significant Events

2.6.1.2 Landing Sink Rate Analysis Using Video (Cameras SLF-North and SLF-South)

Sink rates obtained from video data (because of the medium's inherent lower resolution) are normally only used as sanity checks for the results obtained from the film data. Camera SLF-South was used to determine the landing sink rate of the main gear. The analysis considered approximately two seconds of imagery immediately prior to touchdown. Data was gathered at a sample rate of 30 frames per second. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter y-axis. Scaling information was determined by using the distance between the main gear struts. The vertical difference of the projected main gear point for two successive frames was multiplied by the scaling factor to find the change in height of the main gear over that interval. The main gear height above the runway was determined by assigning the frame of touchdown a height of 0 feet, and cumulatively adding the previous frames. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The main gear sink rate was calculated from the last two seconds, one second, half second and quarter second interval. These rates were 1.6, 0.7, 0.4 and 0.7 feet per second respectively.

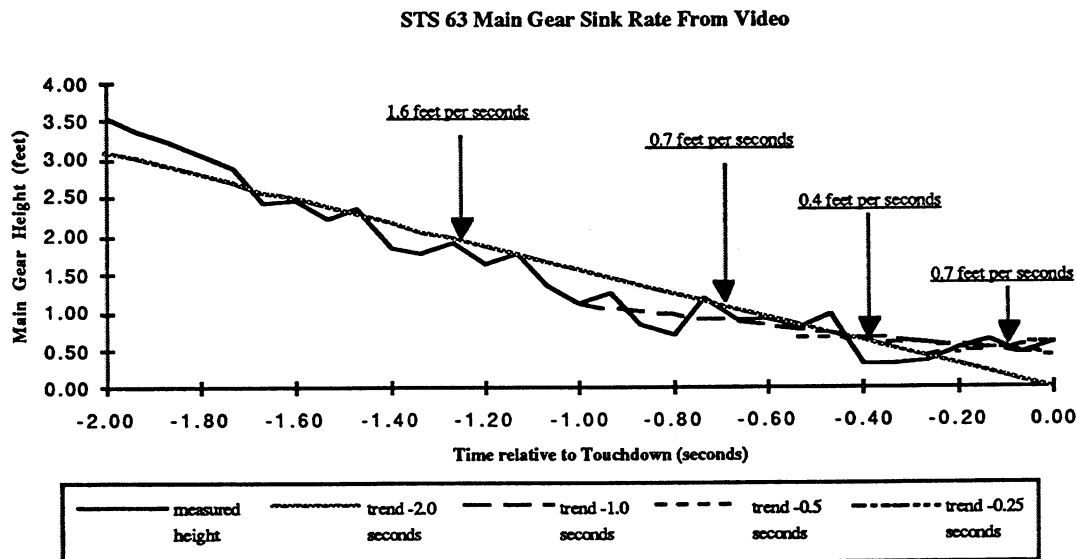


Figure 2.6.1.2a Video Main Gear Sink Rate

2.0 Summary of Significant Events

Camera SLF-North was used to determine the landing sink rate of the nose gear. The analysis considered 1.73 seconds of imagery immediately prior to touchdown. Data was gathered at a sample rate of 30 frames per second. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter y-axis. Scaling information was determined by using the distance between the main gear struts. The vertical difference of the digitized nose gear point from the average of the main gear points was multiplied by the scaling factor to find the height of the nose gear for a single frame. An empirical offset correction was made to produce a calculated height at main gear touchdown of 0 feet. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The nose gear sink rate was calculated from the last 1.73 seconds, one second, half second and quarter second interval. These rates were 3.7, 3.8, 4.4 and 7.6 feet per second respectively.

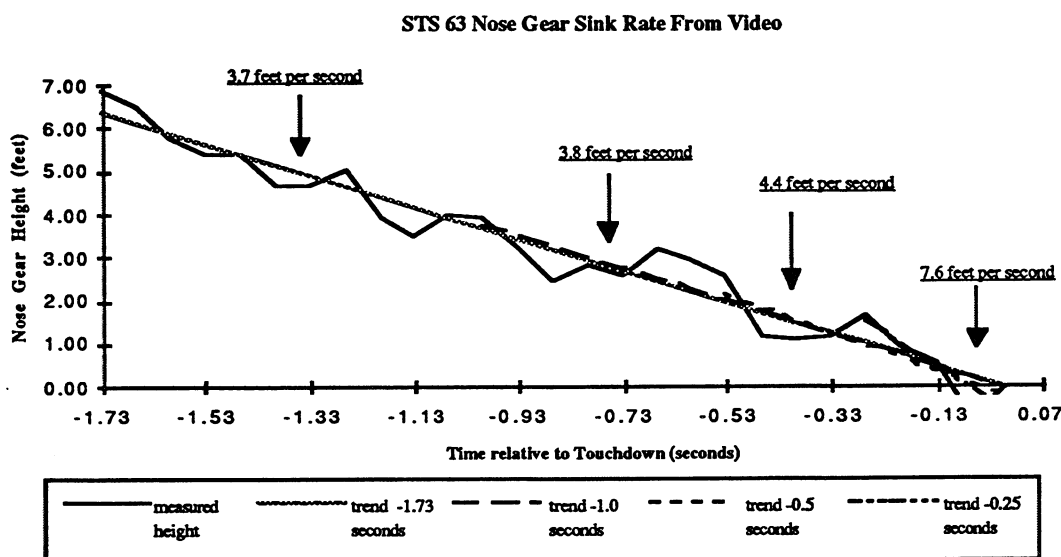


Figure 2.6.1.2b Video Nose Gear Sink Rate

2.6.2 Drag Chute Performance (Task #9) (Cameras EL-7 and EL-9)

The landing of Columbia at the end of mission STS-65 marked the fifteenth deployment of the Orbiter drag chute. The pilot chute door appeared to drift behind the vehicle and pass near the pilot chute after bag release. (See Figure 2.6.2a). An impact with the pilot chute may have occurred. A study of the drag chute door and pilot chute trajectories relative to the Orbiter and the runway has been initiated. Analysis of the event is not yet complete.

The deployment of the drag chute appeared as expected. Event times were obtained from camera KTV-11L except for chute release which was acquired from KTV-15L.

Drag chute initiation	10:38:07.953 UTC
Pilot chute inflation	10:38:08.820 UTC
Bag release	10:38:09.588 UTC
Drag chute inflation in reefed position	10:38:10.756 UTC

2.0 Summary of Significant Events

Drag chute inflation in disreefed configuration	10:38:13.926 UTC
Drag chute release	10:38:42.625 UTC



Figure 2.6.2a **Drag Chute Door Trajectory**

This view of deployment shows the pilot chute housing door as the main chute is being unfurled. A study of the landing videos and films suggests that the door may have contacted the pilot chute after release.



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2.0 Summary of Significant Events

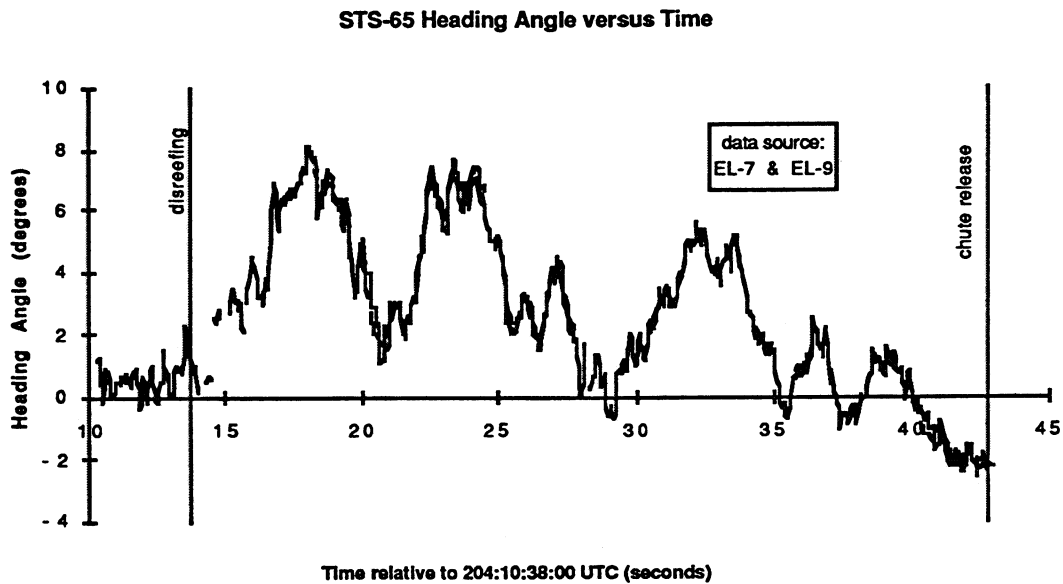


Figure 2.6.2b **Heading Angle Versus Time**

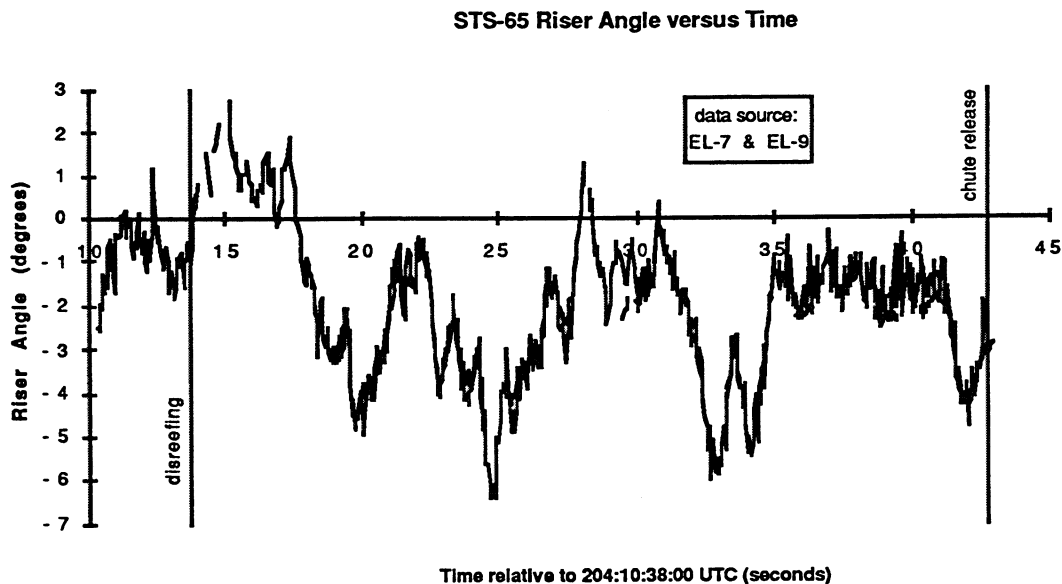


Figure 2.6.2c **Riser Angle Versus Time**

Standard analysis of the drag chute angles as a function of time was performed using the views from the film cameras EL-7 and EL-9. This analysis is used to support the improvement of the aerodynamic math models currently in use. Figure 2.6.2b presents the measured heading angle versus time. Figure 2.6.2c presents the measured riser angle versus time. The maximum measured horizontal chute deflection (heading angle) was approximately 8.0 degrees to the starboard side of the vehicle. The vertical chute

2.0 Summary of Significant Events

deflection (riser angle) ranged from -6.5 to +2.7 degrees relative to the Orbiter coordinate system.

2.6.3 Damage to Left OMS Pod TPS (*Task #15*)

The STS-65 Orbiter Post Landing Inspection Debris Assessment Team reported seven debris hits to the left OMS pod leading edge. KSC reported that the damage may have been the result of an ice impact. Ice could have formed on the waste water dump nozzle due to an on-orbit problem with this system.

On-orbit handheld Hasselblad camera views imaging the left OMS pod were examined for visual indications of this damage. The largest tile damaged site appeared to be in good condition when the first on-orbit photograph of the left OMS pod was taken on July 09, 1994 (19:58:21 UTC) and also on the last on-orbit photograph of the area on July 20, 1994 (10:51:34 UTC). This time period includes the suspect waste water dump on July 11, 1994 (approximately 07:45 UTC). Analysis of the on-orbit Hasselblad photography suggests that the damage happened after the last Hasselblad view was obtained and could have occurred during de-orbit, re-entry, or landing. The video view of the payload bay door closing does not have sufficient detail of the left OMS pod tiles to determine if the damage was present at that time.

2.0 Summary of Significant Events

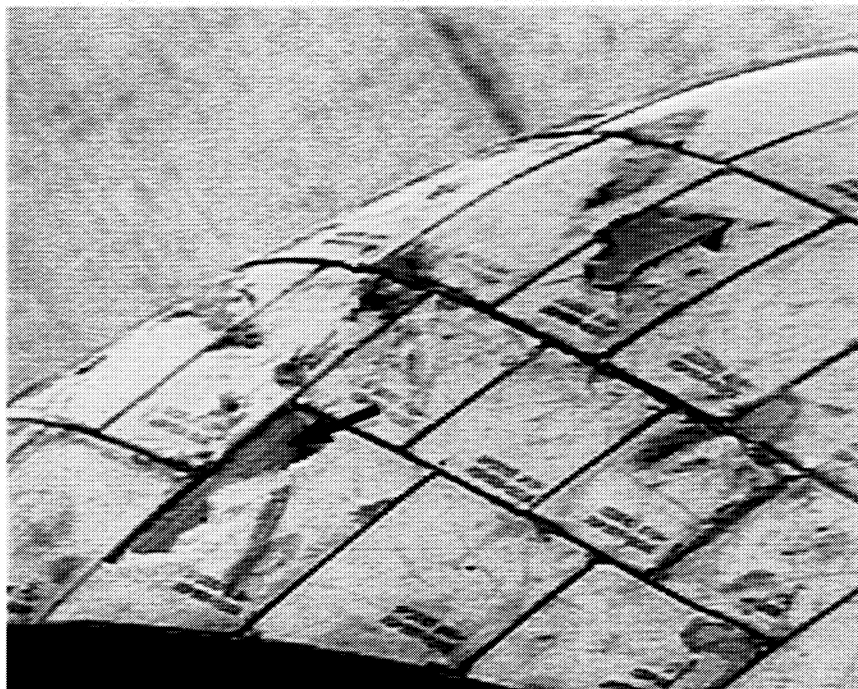
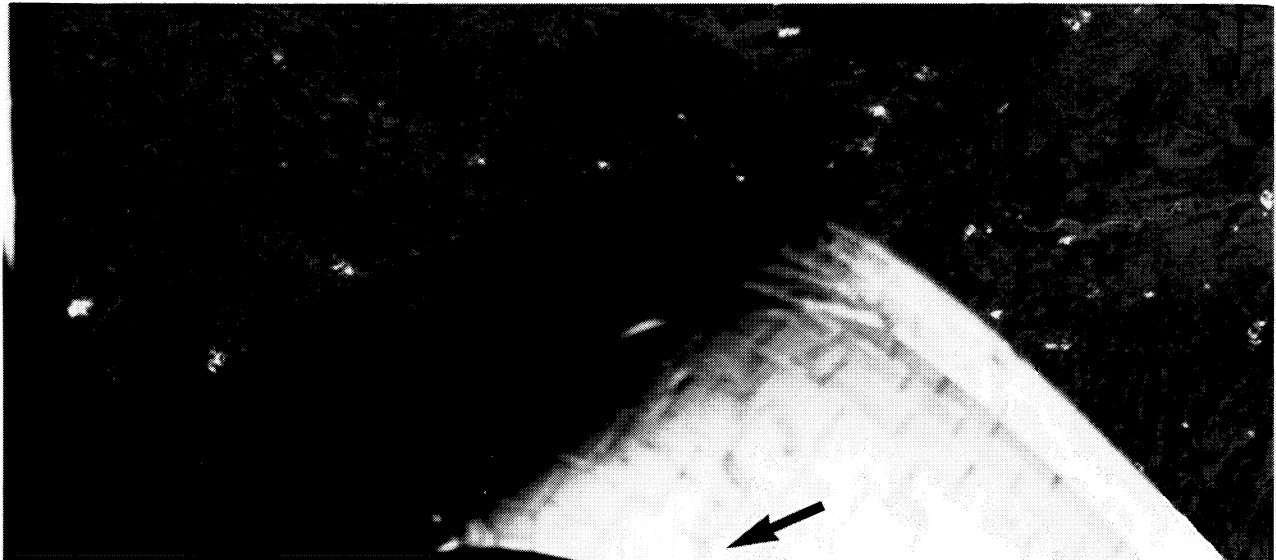


Figure 2.6.3 View of the Left OMS Pod Prior to De-orbit and During the Post Landing Inspection

The picture at the top is an on-orbit Hasselblad image taken of the left OMS pod area prior to the payload bay doors being closed. The image below was taken during the post-landing walkaround and shows the largest tile damage site (8" x 4" x 2") with half of the visible damage extending down to the substrate.



2.0 Summary of Significant Events

2.7 OTHER NORMAL EVENTS

Other normal event observed include: ET twang, DMHS vibration noted at SSME ignition, right and left inboard and outboard elevon motion visible after SSME ignition and at liftoff, ice and vapor from the Ground Umbilical Carrier Plate (GUCP) during SSME startup and ET GH2 vent arm retraction, acoustic waves noted in the SRB exhaust cloud, ET aft dome outgassing, vapor from the SRB stiffener rings after liftoff, white flashes near the SRB plume, expansion waves, charring of the ET aft dome during ascent, dark puffs in SRB exhaust prior to SRB separation, SRB plume brightening and slag debris in the SRB exhaust plume during and after SRB separation.

MLP events observed include: Fixed Service Structure (FSS) deluge water spray activation and Mobile Launch Platform (MLP) water dump activation (although the northwest MLP deluge rainbird appeared slow to start).

2.8 OTHER

An attempt was made to use two infrared scanners to determine the temperature of the Orbiter tires during landing. Hardware and alignment problems hampered acquisition of data at touchdown. Modifications to the procedures have been made and the scanners will be used to gather data on the STS-68 landing.

A detailed timeline of the SSME and SRB ignition sequences was generated and sent to R. Fletcher/VF5.



Appendix B. MSFC Photographic Analysis Summary

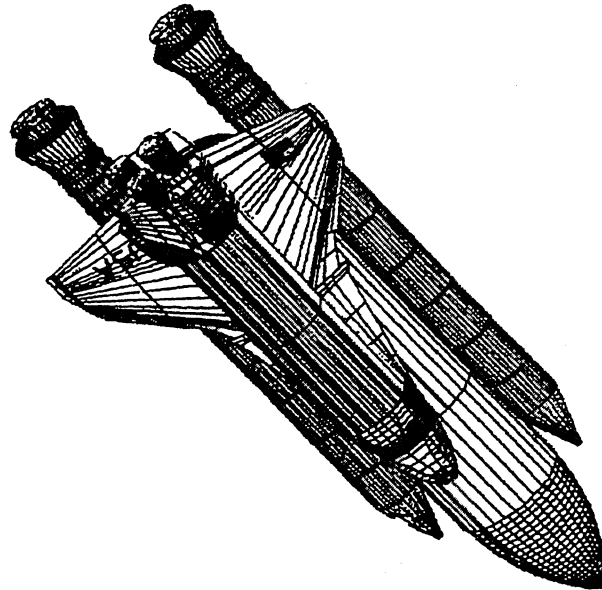




National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT STS-65



B-1

MSFC - Form 454 (Rev. October 1992)

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT


STS-65

FINAL

PREPARED BY:


M. COVAN, J. HIXSON
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:



JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

APPROVED BY:



T. RIECKHOFF, MSFC/EP24
B. LINDLEY-ANDERSON, MSFC/EP24
D. BRYAN, MSFC/EP24

STS-65 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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- APPENDIX B - INDIVIDUAL VIDEO CAMERA ASSESSMENT *

* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

August 3, 1994

I. INTRODUCTION

The launch of space shuttle mission STS-65, the seventeenth flight of the Orbiter Columbia occurred on July 8, 1994, at approximately 11:43 A.M. Central Daylight Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage exists and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard the vehicle, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-65 included, but were not limited to the following:

- a. Overall facility and shuttle vehicle coverage for anomaly detection
- b. Verification of cameras, lighting and timing systems
- c. Determination of SRB PIC firing time and SRB separation time
- d. Verification of Thermal Protection System (TPS) integrity
- e. Correct operation of the following:
 1. Holddown post blast covers
 2. SSME ignition
 3. LH2 and LO2 17" disconnects
 4. GH2 umbilical
 5. TSM carrier plate umbilicals
 6. Free hydrogen ignitors
 7. Vehicle clearances
 8. GH2 vent line retraction and latch back
 9. Vehicle motion
 10. External Tank TPS condition after separation (DTO-0312)

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-four of fifty-four requested cameras as well as video from twenty-four of twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-65.

**Camera data received at MSFC
for STS-65**

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	3	3	6
Tracking	0	15	11
Onboard	2	2	0
Totals	34	20	24
Total number of films and videos received:			78

An individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

All films of the STS-65 launch were of excellent quality. Lighting conditions at the time of launch were optimum. Little or no distortion was apparent due to the atmospheric conditions except for the extreme long-range cameras both north and south of the flight path. All requested cameras operated properly.

b. Onboard Camera Coverage:

The astronaut hand-held coverage of the external tank after separation provided thirty-eight frames of 35mm film. The coverage was considered fair. All three films from the umbilical well cameras were received. All cameras operated properly photographing the SRB's and ET during and after separation.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: pad debris rising and falling as the vehicle lifts off, debris north of MLP ejected from SRB blast holes, debris induced streaks in the SSME plume, ice falling from the 17 inch disconnects and umbilicals, and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detection paper and purge barrier material. Body flap and inboard right elevon motions were noted during ascent.

b. Condensation Cloud

An unusual condensation cloud formed as the vehicle ascended at 57.5 s MET. This cloud, as seen by camera TV5 is shown in Figure 1. The cloud did not appear to emanate from the vehicle. This cloud appears to form as a result of the shock wave passing through saturated air in the upper atmosphere. Figure 2 from camera ET-207 shows a close view at the time of cloud formation.



Figure 1. Condensation Cloud as seen from Camera TV5

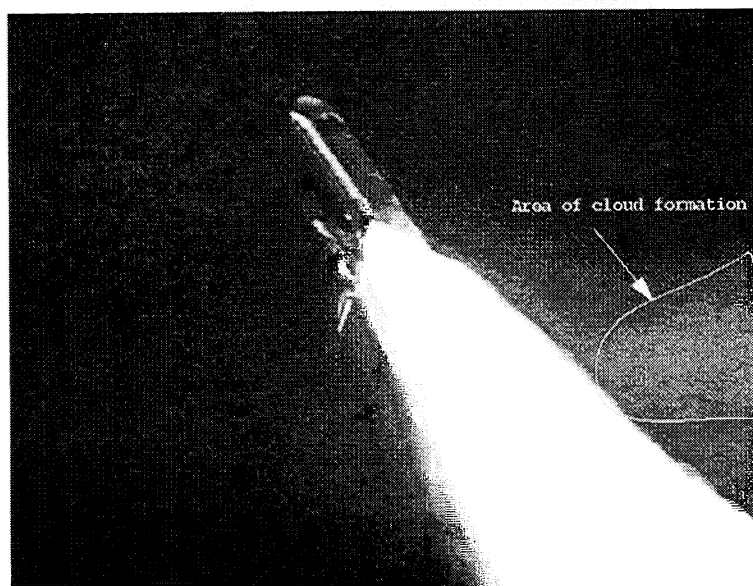


Figure 2. Condensation Cloud as seen from Camera ET-207



c. Condensation Collar

As the vehicle ascended, the condensation collar that usually forms around the vehicle was more pronounced and persisted longer due to the moisture content of the atmosphere. This collar is shown in Figure 3.

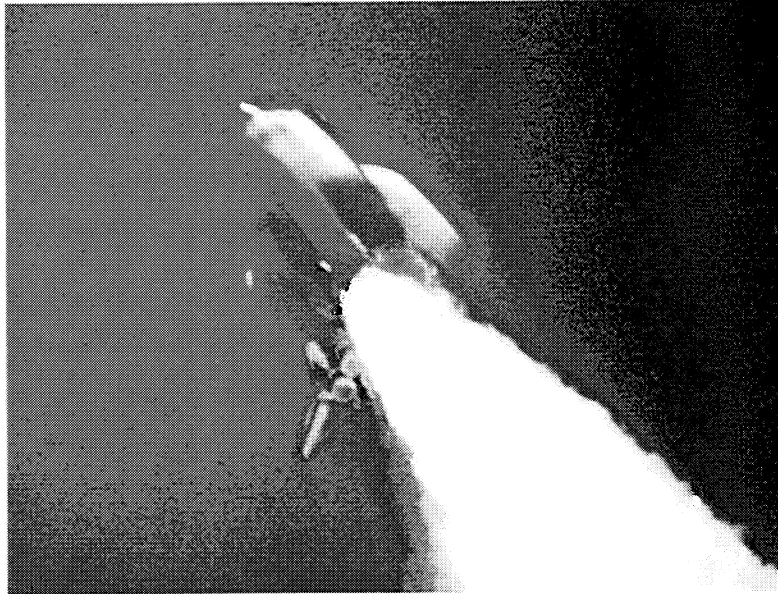


Figure 3 Condensation Collar as observed from Camera E-223

d. Thermal Curtain Tape

Loose thermal curtain tape was noted just after lift-off from camera E-15 as shown in Figure 4.

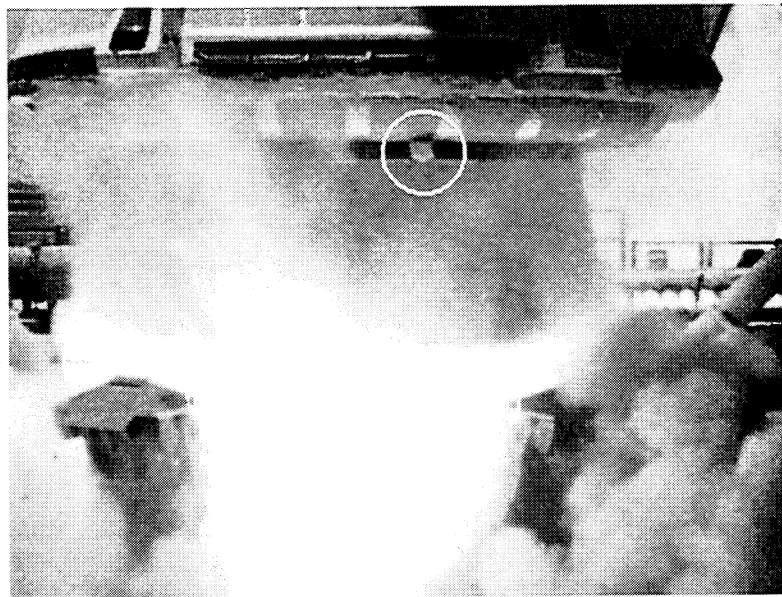


Figure 4 Loose Thermal Curtain Tape at Liftoff



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During ascent, at 49.23 s MET a piece of thermal curtain tape was noted falling from the vehicle by cameras E-212 and E-223 as shown in Figures 5 and 6 respectively.

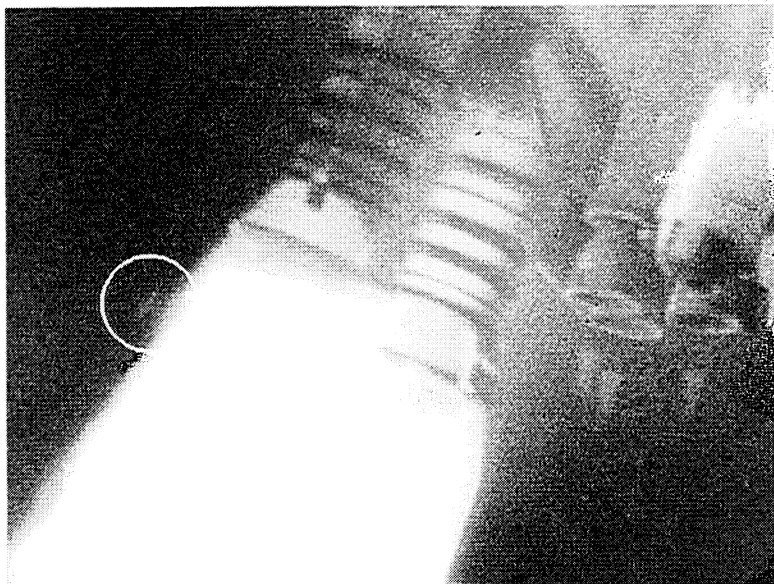


Figure 5 Thermal Curtain Tape as seen from Camera E-212

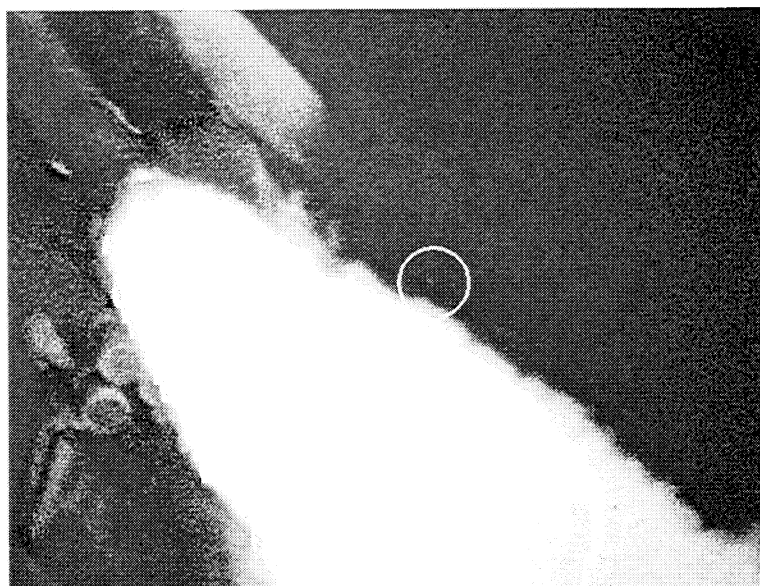


Figure 6 Thermal Curtain Tape as seen from Camera E-223

e. ET Separation Debris

During ET separation, a large piece of debris was noted on the right side of the tank from the 16mm onboard camera. This debris is depicted in Figure 7.



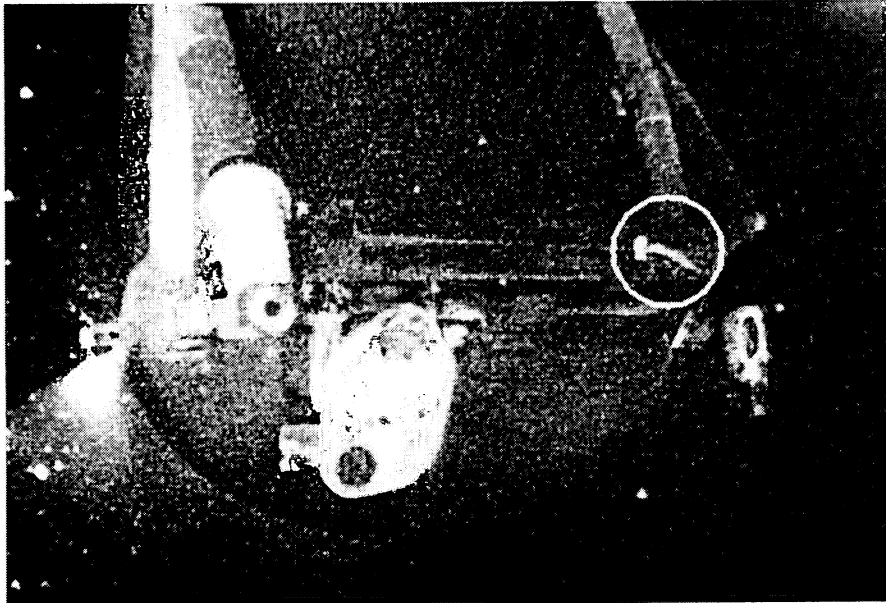


Figure 7 ET Separation Debris from Onboard Camera

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times are determined from cameras that view the SRB holddown posts numbers M-1, M-2, M-5 and M-6. These cameras record the explosive bolt combustion products.

HOLDDOWN POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	189:16:43:00.023
M-2	E-8	189:16:43:00.023
M-5	E-12	189:16:43:00.023
M-6	E-13	189:16:43:00.021

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 30 inches. Figure 8 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. A positive horizontal displacement represents motion in the -Z direction. These data were derived from film camera E-79.



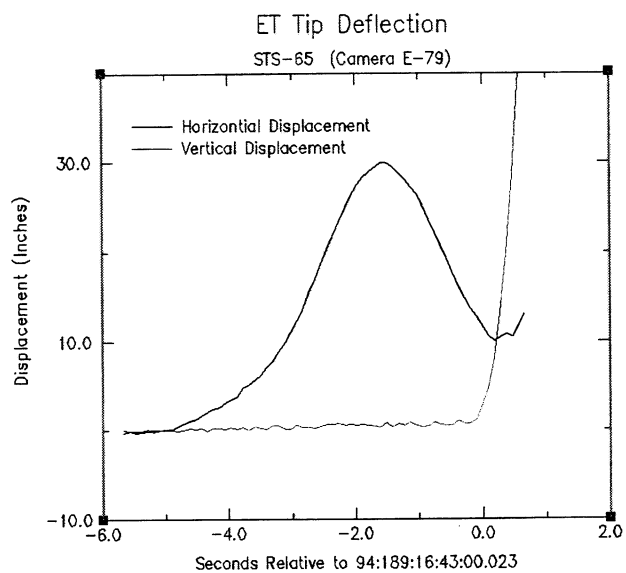


Figure 8 ET Tip Deflection

c. SRB Separation Time:

SRB separation time for STS-65 was determined to be 189:16:45:03.53 UTC as recorded by several tracking cameras.





APPENDIX C

ENGINEERING PHOTOGRAPHIC ANALYSIS SUMMARY REPORT

STS-65

AUGUST 17, 1994

PREPARED BY:

R. Ramon

**R. RAMON
MISSION OPERATIONS
ROCKWELL/DOWNEY**

APPROVED BY:

N.L. Geiser

**N.L. GEISER
CAM, SHUTTLE INTEGRATION - DESIGN
ROCKWELL/DOWNEY**

APPENDIX C

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1.0 INTRODUCTION

The launch of Columbia (OV-102) on mission STS-65 occurred on July 8, 1994 at 9:43 a.m. PDT/GMT 189:16:43:00.013 from Launch Complex 39A (LC 39A), Kennedy Space Center (KSC). Landing occurred on July 23, 1994 at the KSC Shuttle Landing Facility (SLF) at 3:38 a.m. PDT/GMT 204:10:38.00. Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39A Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, uprange and downrange tracking sites, and SLF. Rockwell received launch films from 80 cameras (56 cine, 24 video) and landing films from 28 cameras (14 cine, 14 video) to support the STS-65 photographic evaluation effort.

2.0 ENGINEERING PHOTOGRAPHIC ANALYSIS SUMMARY

2.1 GENERAL OBSERVATIONS

Overall, the films showed STS-65 to be a clean flight. Several pieces of ice from the ET/Orbiter umbilical were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver. Charring of the ET aft dome, recirculation and brightening of the SRB plumes were normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal.

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Mission Elapsed Time (MET), as is normal. All blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH2 vent line carrier dropped normally and latched securely with a slight rebound. No anomalies were identified with the ET/ORB LH2 umbilical hydrogen dispersal system hardware.

2.0 SUMMARY OF SIGNIFICANT EVENTS OBSERVED

2.2.1 MLP AND LIFTOFF EVENTS

2.2.1.1 Orange Vapor (Possibly Free - burning Hydrogen)

On cameras E-3, E-5, E-17, E-18, E-19, E-20 and E-30, Orange Vapor (possibly free burning hydrogen) was noted below the SSME bells just prior to ignition. This vapor has been observed on previous flights and no follow-on work is scheduled.

2.2.1.2 Flash in SSME plume at SSME ignition

Flashes were noted in the SSME #1 and SSME #3 plumes at SSME ignition (cameras OTV-051, E-2, E-3, E-5, E-19 and E-20). Flashes in the SSME plumes have been seen on previous missions and are probably caused by RCS paper covers. No follow-up action is planned.

2.2.1.3 LH2 and LO2 TSM T-0 Umbilical Disconnect Debris

On cameras E-5, E-17, E-18, E-19 and E-20, normal ice debris was seen falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at SSME ignition through liftoff. No damage to the vehicle was observed. No follow-up action is planned.

2.2.1.4 LH2 and LO2 ET/Orbiter Umbilical Debris

On cameras OTV-009, OTV-063, E-5, E-6, E-15, E-18, E-25, E-26 and E-31, normal ice debris was seen falling from the LH2 and LO2 ET/Orbiter Umbilical areas at SSME ignition through liftoff. Several pieces contacted the LH2 umbilical door sill, but no damage was detected. No follow-up is planned.

2.2.1.5 Loose Thermal Curtain Tape on Right SRB

Two pieces of loose thermal curtain tape were noted on the right SRB during liftoff on cameras E-10 and E-15. Loose thermal curtain tape has been seen on previous missions and no follow-up action required.

2.2.2 ASCENT EVENTS

2.2.2.1 Debris near SRB's and left inboard Elevon

On cameras E-54, E-213 and E-220, several pieces of light colored debris were seen falling aft between the SRB's and near the left inboard elevon at approximately 29 to 30 seconds MET. None of the debris appeared to impact the vehicle. No follow-up action is planned.

2.2.2.2 Flare in SSME plume

A flare was noted in the SSME plume during ascent (29 to 30 seconds MET) on camera E-222. Flares have been noted on previous missions. No follow-up action is planned.

2.2.2.3 Condensation Vapor Cloud Near SRB plume

During ascent a large white vapor cloud was seen at the ET and SRB side of the SSV at 57 to 59 seconds MET (near Mach 1.3) on cameras TV-4A, TV-7A, TV-21A, E-213 and E-222. An analysis (see figures C-1 through C-9) was performed by the Aerodynamics

group which included: (1) reviewing the launch films, (2) reviewing the LH2 tank and LO2 tank ullage pressures, and (3) an air flow analysis. The results of the LH2 and LO2 tank ullage pressure data and the vent valve data indicated that there were no apparent venting activities in the LH2 and LO2 tanks. A flow analysis was performed based on the preflight predicted trajectory, the preflight rawinsonde balloon measured weather data, and the existing airloads database. The analysis showed that water vapor condensation induced by air flow expansion over ET, SRB, and Orbiter will occur under the flight conditions. Regions on the Orbiter, ET, and SRB where vapor condensation would occur (due to local air temperature dropping below dew point) were determined for Mach 1.25. The results of these calculations concluded that this "cloud" is an aerodynamic induced water vapor condensation phenomenon. This phenomenon has been observed on previous flights (STS-48 and STS-62) and is not considered a vehicle anomaly. No follow-on work is scheduled. All findings were corroborated by JSC and KSC and presented to the appropriate NASA and Rockwell management.

2.2.3 ON ORBIT EVENTS

No significant on orbit events were observed.

2.2.4 LANDING EVENTS

The landing of STS-65 occurred on Runway 33 at the KSC Shuttle Landing Facility. Good video and film coverage were obtained. Main landing gear touchdown occurred at 204:10:38:00 GMT and nose landing gear touchdown occurred at 204:10:38:17 GMT with wheel stop occurring at 204:10:39:09 GMT.

2.2.4.1 Drag Chute System Compartment Door contact with Pilot Chute

The flight marked the sixteenth use of the Orbiter drag chute. The drag parachute system performed as expected. All sequenced events occurred as expected, however, after the pilot chute had completed its function and fallen to the ground, the drag chute system compartment door contacted the pilot chute (cameras EL20 and EL2). No damage to the pilot chute was found during post-landing inspection. This is not an issue and no follow-up action has been requested.

2.2.4.2 OMS Pod leading edge damage

The post-landing inspection revealed tile damage on the left OMS pod leading edge. The damage site measured 8"x 4" x 2" and may have been the result of an ice impact.

2.2.4.3 Dome Mounted Heat Shield thermal blanket damage

During the post-landing walk around it was noted that the Dome Mounted Heat Shield (DMHS) closeout blankets were torn on SSME #1 at the 6 O'clock position. The DMHS blankets were also loose on SSME #2 (3 O'clock position) and SSME #3 (2 O'clock position).

2.2.5 OTHER NORMAL EVENTS

The following events have been reported on previous missions and observed on STS-65. These are not of major concern, and include: Ice debris falling from the ET/Orbiter Umbilical disconnect area, Debris (Insta-foam, water trough) in the holddown post area and MLP, Charring of the ET aft dome, ET aft dome outgassing after liftoff, RCS Paper debris, Recirculation or expansion of burning gasses at the aft end of the SLV prior to SRB separation, Slight TPS erosion on the base heat shield during SSME start-up, Twang motion, Body flap motion during the maximum dynamic pressure (MAX-Q) region which appeared to have an amplitude and frequency similar to those of previous missions, Linear optical distortion, possibly caused by shock waves or ambient meteorological conditions near the vehicle, during ascent, Slag in SRB plume after separation, Vapor from the SRB stiffener rings after liftoff, and Condensation on the Orbiter forward fuselage, ET nose and SRB frustums during ascent.

2.2.6 OMRSD FILE IX VOL 5 REQUIREMENTS

2.2.6.1 Clearance between left SRB and ET vent umbilical

Camera E33 and E41 - OMRSD File IX Vol. 5, Requirement No. DV08P.010 requires an analysis of launch pad film data to verify that the initial ascent clearance separation between the left SRB outer mold line and the falling ET umbilical structure does not violate the acceptable margin of safety.

A qualitative assessment has been conducted and positive clearances between the left SRB and the ET vent umbilical have been verified. The films showed nominal launch pad hardware performance, and no anomalies were observed for the SRB body trajectory.

2.2.6.2 Clearance between SRB nozzles and holddown posts

Cameras E7-16-OMRSD File IX Vol. 5, Requirement No. DV08P.020 requires an analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.

A qualitative assessment of the launch films has been completed. No anomalies were observed for the SRM nozzle trajectory and positive clearances between the SRB nozzles and the holddown posts were verified.

STS-65 GASEOUS / VAPOR CLOUD ANALYSIS

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AERODYNAMICS

FIGURE C-1

C-5

PHENOMENON OBSERVED

- o STS-65 LAUNCH FILMS SHOW SIGNIFICANT GASEOUS/VAPOR CLOUD APPEARS NEAR THE LEEWARD SIDE OF SSV DURING ASCENT
 - o TIME OF OCCURRENCE ~ T+ 57 TO T+59 SEC.
 - o ALTITUDE ~ 33500 FT. TO 35700 FT.
 - o MACH NO. ~ 1.3
 - o DIMENSION ~ 500 FT. WIDE AND 1000 FT. LONG
- o SIMILAR PHENOMENON ALSO OBSERVED ON STS-48
- o SIMILAR BUT LESS PRONOUNCED PHENOMENON OBSERVED ON STS-62

FIGURE C-2

SUMMARY OF ANALYSIS

- o VERIFIED NO ORBITER SUBSYSTEM ANOMALIES
 - o RCS, PRSD, APU
 - o ENVIRONMENTAL CONTROL
- o NO APPARENT VENTING ACTIVITIES ON ET
 - o ULLAGE PRESSURES ON LH2 TANK AND LOX TANK APPEAR TO BE NORMAL
 - o LH2 AND LOX VENT VALVES REMAINED CLOSED
 - o EVEN IF VENTING DID OCCUR, VAPOR CLOUD IS UNLIKELY TO GROW TO 500 BY 1000 FT IN DIMENSION WITHIN 2 SECONDS
- o WATER VAPOR CONDENSATION INDUCED BY AIR FLOW EXPANSION OVER SSV IS THE MOST LIKELY CAUSE OF THE OBSERVED PHENOMENON
 - o CALCULATION BASED ON $M = 1.25$ $\alpha = -4^\circ$ SHOWS VAPOR CONDENSATION WILL OCCUR ON ET, SRB AND ORBITER
 - o ACTUAL TRAJECTORY $\alpha \sim -5^\circ$ WOULD RESULT IN MORE PRONOUNCED CONDENSATION ON ET AND SRB

FIGURE C-3

VAPOR CONDENSATION INDUCED BY FLOW OVER SSV

- o WEATHER BALLOON MEASURED DEW POINT UP TO ALTITUDE OF 32920 FT.
- o SAMPLE CALCULATION MADE AT MACH 1.25
 - o PREFLIGHT TRAJECTORY AND WEATHER BALLOON DATA SHOW
 $Q = 672.2 \text{ PSF}$, $T = 425^\circ\text{R}$, $\text{DEW POINT} = 415^\circ\text{R}$
 - o METHODOLOGY
 - o USE LOCAL STATIC PRESSURE FROM AIRLOADS DATA BASE TO CALCULATE LOCAL MACH
 - o USE LOCAL MACH TO CALCULATE LOCAL AIR TEMP.
 - o IF LOCAL AIR TEMP. $<$ DEW POINT, WATER VAPOR CONDENSATION WILL OCCUR
 - o REGIONS WHERE CONDENSATION WILL OCCUR FOR $\alpha = -4^\circ$
 - o SRB BOTTOM ($\Phi = 0$) $X/L : 0.10 \sim 0.30$
 - o ET BOTTOM ($\Phi = 0$) $X/L : 0.10 \sim 0.29 \quad 0.43 \sim 0.57$
 - o ORBITER TOP ($\Phi = 180$) $X/L : 0.19 \sim 0.56 \quad 0.95 \sim 1.07$
- o CLOUD STAYS VISIBLE WHILE VEHICLE CONTINUES ITS ASCENT UNTIL THE CLOUD IS VAPORIZED THROUGH HEAT TRANSFER

FIGURE C-4

STS-65 PRELAUNCH WEATHER BALLOON DATA

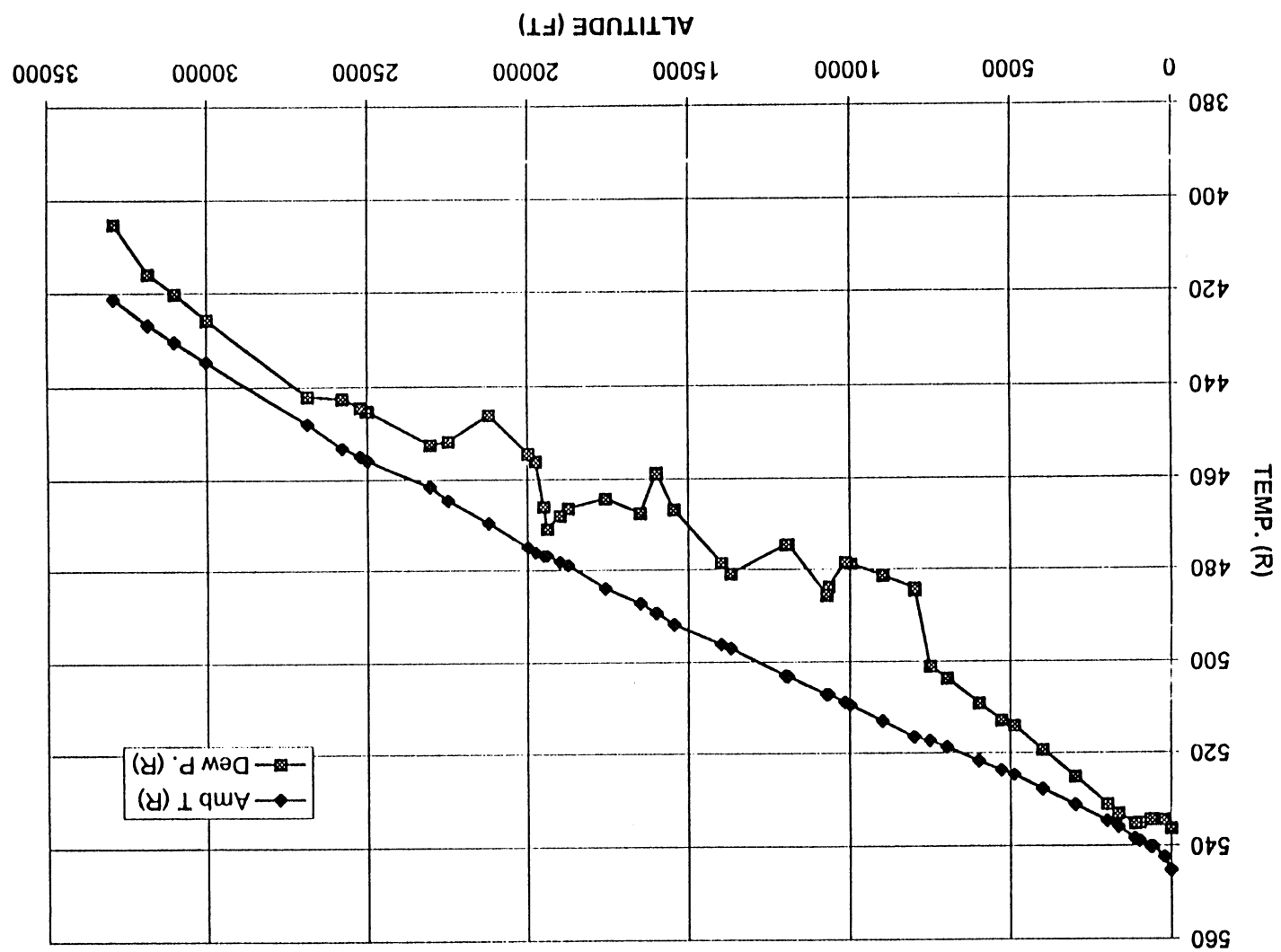


FIGURE C-5

ESTIMATED AIR TEMPERATURE DISTRIBUTION OVER SRB FOR STS-65

MACH = 1.25 ALPHA = - 4 DEG. PHI = 0 DEG.

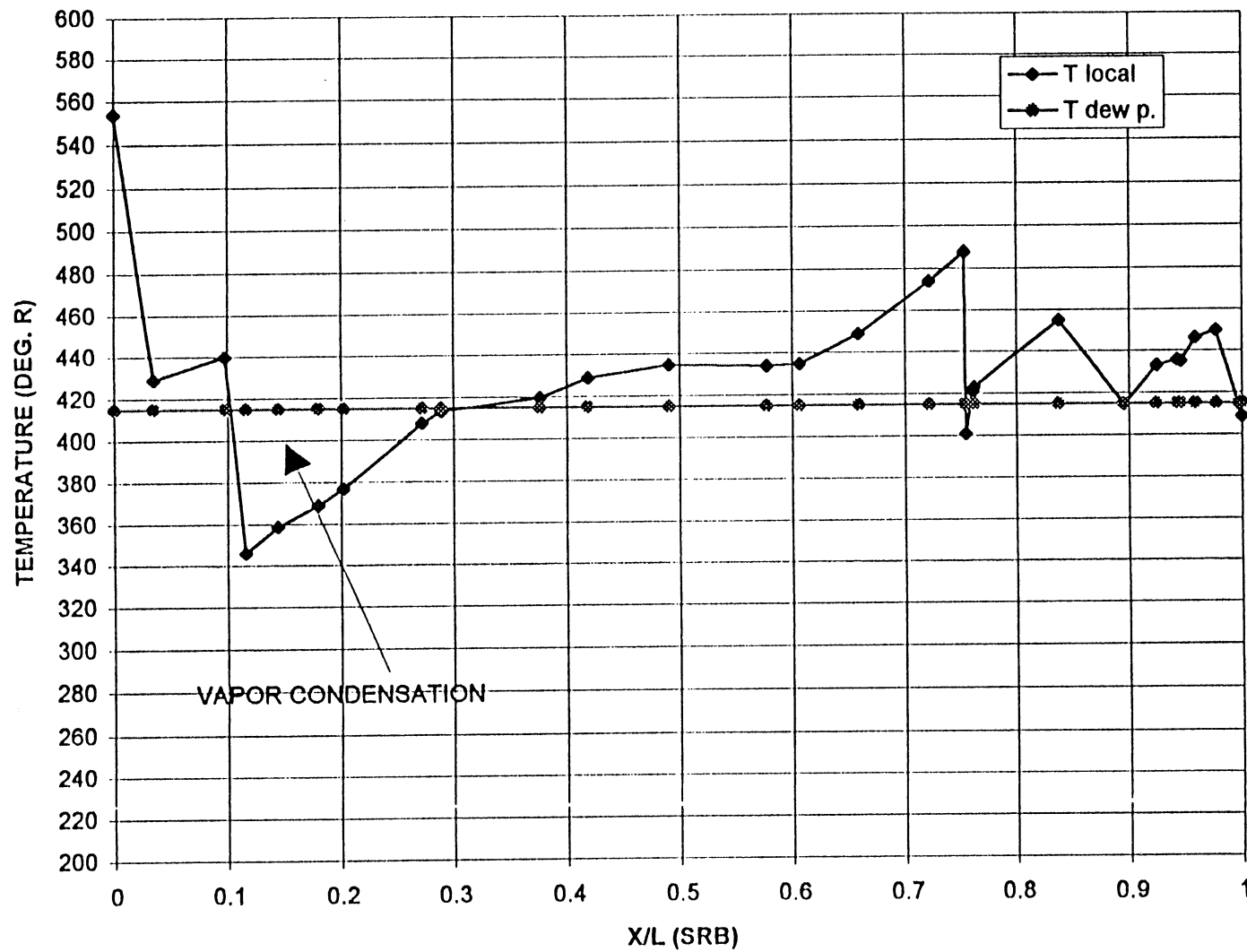


FIGURE C-6

ESTIMATED AIR TEMPERATURE DISTRIBUTION OVER ET FOR STS-65

MACH = 1.25 ALPHA = - 4 DEG. PHI = 0 DEG.

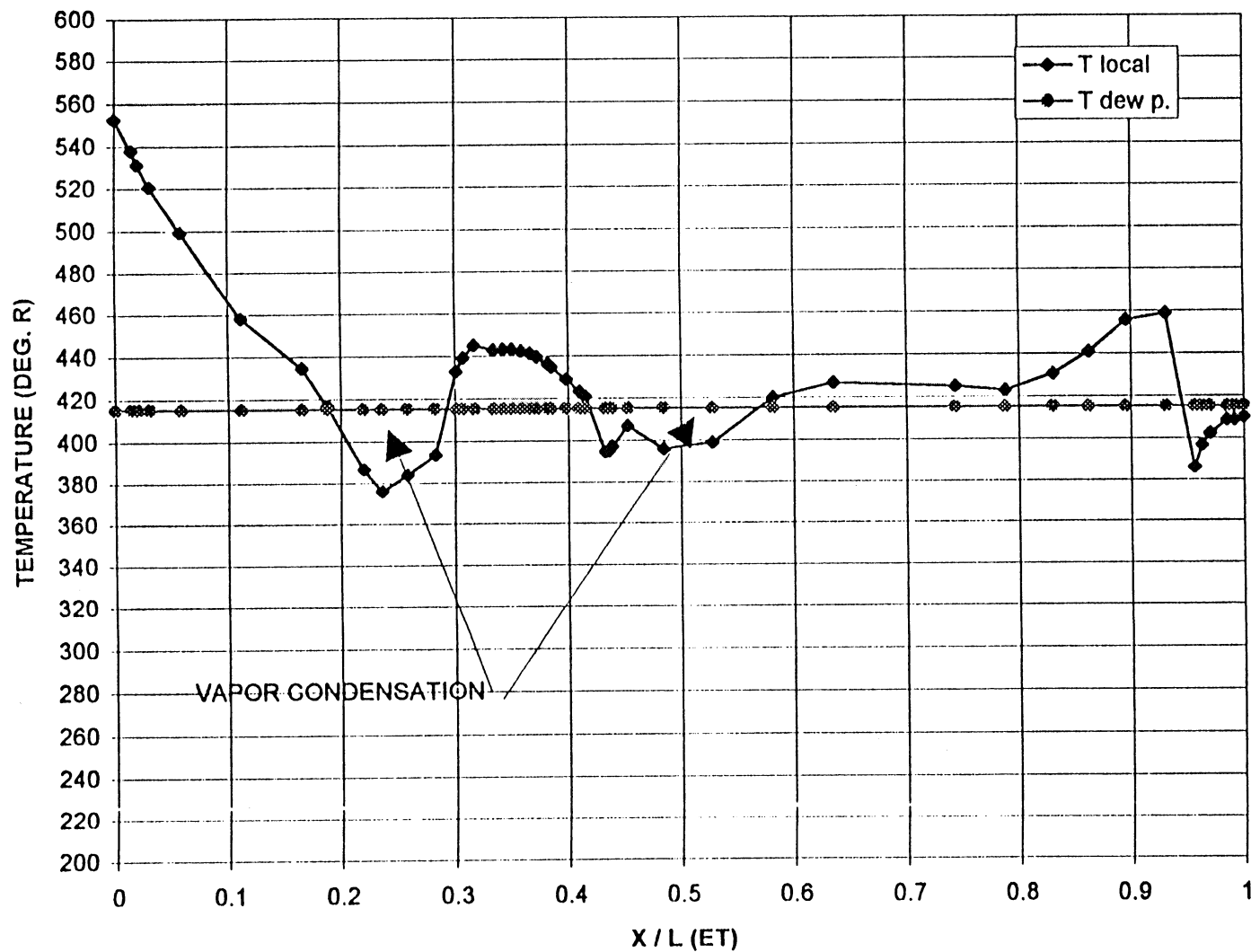


FIGURE C-7

ESTIMATED AIR TEMPERATURE DISTRIBUTION OVER ORBITER FOR STS-65

MACH = 1.25 ALPHA = - 4 DEG. PHI = 180 Deg.

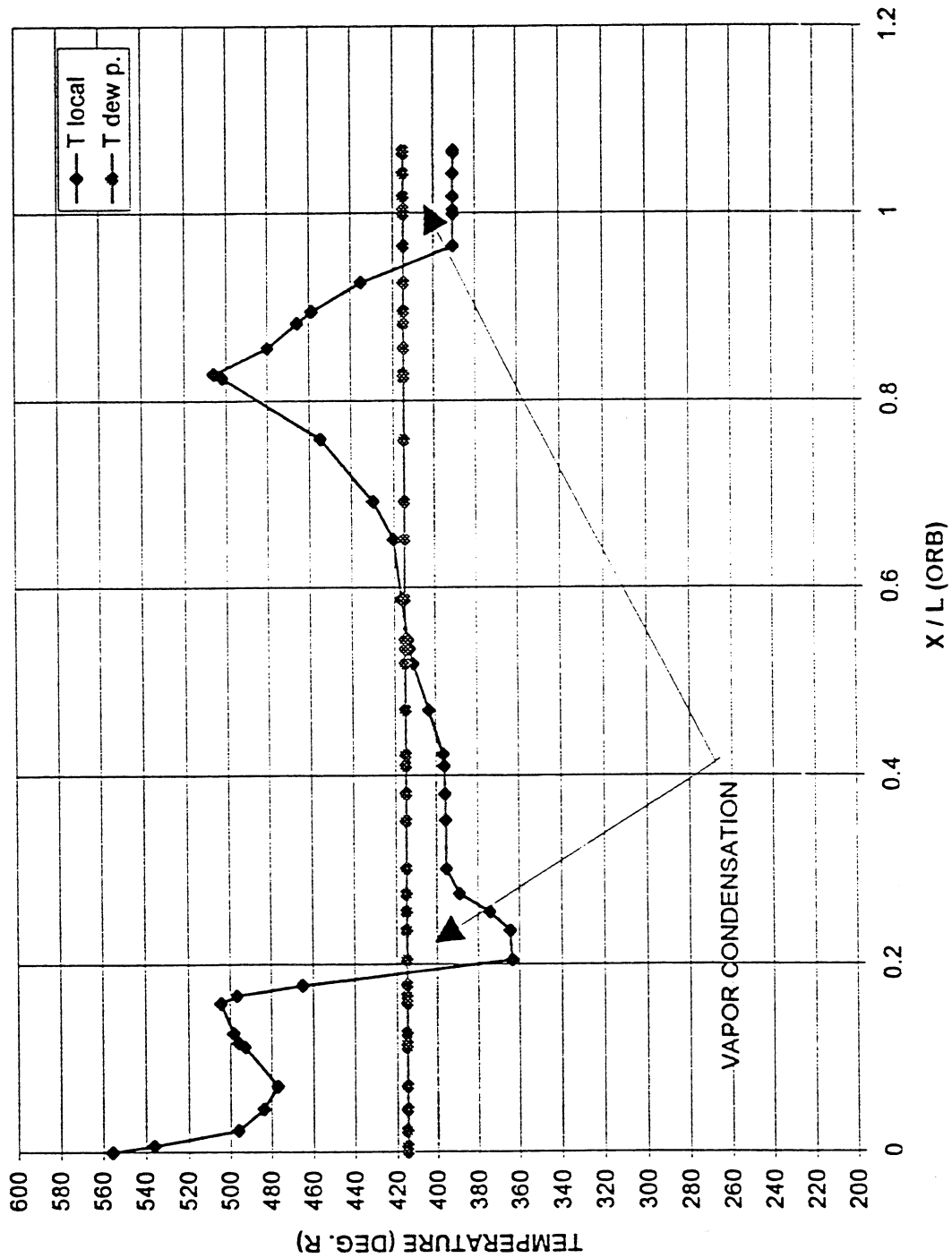


FIGURE C-8

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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